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DTU Wind Energy
Department of Wind Energy

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Peter Hauge, Head of Department

INTERNATIONAL COOPERATION ESSENTIAL FOR THE DEVELOPMENT OF WIND ENERGY

DTU Wind Energy is a department of the Technical University of Denmark, specifically focusing on wind energy and with a unique combination of research and value creation through education, innovation and scientific consultancy. Research is carried out together with partners in Denmark and internationally, in particular from Europe. The wind energy sector is global, and the department is active in e.g. Asia, Africa and the Americas.

The wind energy research and industrial sector in Denmark is second to none. This was evaluated by Damvad in 2014 and documented in the report "Research and industrial positions of strengths in the Danish wind energy sector" (in Danish "Forsknings- og erhvervsmæssige styrkepositioner i den danske vindenergisektor"). In terms of scientific publications Denmark is the top-5 in absolute numbers and leading in terms of citations. The publicly funded research in Denmark only comprises 20 % of the total, as the private sector invest 4 times as much in research and development. Most companies in the wind energy sector assess the cooperation with universities and public institutes on research, development and innovation as having created value for the company, while two-thirds expect the public research and development to continue to be very important for the development of the industry for the next 5-10 years.

The department is a substantial part of the public wind energy research sector in Denmark and is happy to acknowledge and share the results of the evaluation with partners at DTU and other institutes in Denmark. However, the report also shows that the Danish wind energy sector meets growing competition internationally for both research and industry. Although employment and public research funding in Denmark is fairly stable, other countries in Europe, America and Asia demonstrates higher growth rates for both public research and industrial exports.

The development and deployment of wind energy is global, and the industry based in Denmark operates on an international scale. In many countries, including the European, onshore wind power is one of the most competitive sources of new electricity capacity available, and the leveled cost of energy from onshore wind is now within the

Vision:

- DTU Wind Energy is a globally leading department for wind energy with technical-scientific competences in the international front and with a unique integration of research, education, innovation and public/private sector consulting.
- DTU Wind Energy is a key contributor to the realization of the vision of Denmark as a "Wind Power Hub" and the activities support and develop the global wind energy sector with a special effort on national industrial development and innovation.

Mission:

- To develop new opportunities and technology for global and Danish exploitation of wind energy and improve the competitiveness compared to other energy sources.
- To develop technical-scientific knowledge and competencies in key fields, which are central for the development and use of wind energy and provide the basis for advanced education at DTU.
- To facilitate the implementation and exploitation of research results through research-based consultancy and services to industry and the public sector, innovation and education comprising training courses at DTU.

same cost range, or even lower, than for fossil fuels[1] . Nevertheless, it is not self-evident that Denmark will maintain its position as a leading center of wind energy technology development and receive its part of the expected employment and economic growth in the sector. It will take a focused effort for Denmark to maintain its position and reach the opportunities.

Universities play an important role for the full industrial eco-system by strengthening the international industrial competitiveness through its contribution to innovation and development, the creation of new companies, science-based advice and services as well as education of highly qualified staff to the sector.

Hence, DTU Wind Energy finds international cooperation very important in order to support the wind energy sector, not only in our research projects where we can complement our scientific strengths with knowledge from other partners, but also in our education, innovation and consultancy undertakings. Sharing the Danish approach opens markets, provide access to knowledge from other national research programs, and a visible international profile attracts students to Denmark for a future career in wind energy.

Within Europe the department coordinates several large projects funded by EU FP7. In 2014 we led 5 EU projects and participated in approximately 40 in total. The year saw the start of the Integrated Research Program on Wind Energy (IRPWIND), which brings the European Energy Research Alliance's Joint Program on Wind Energy, also led by the department, onto a new stronger level through its combination of coordination and support actions and research activities. The Joint Program now comprises 42 European partners, 7 sub-programs dealing with topics from wind conditions to research infrastructure, each with joint projects and activities, a joint strategy and an annual action plan, a mobility scheme etc. Other important European research projects in 2014 are INNWIND, which focuses on new innovation for very large turbines; DTOC, which develops an integrated design tool for offshore clusters based on partners computational research tools, and DEEPWIND on the development of an innovative vertical-axis floating offshore wind turbine. The list is long and includes research projects with partners in many parts of the world including Africa, the Americas and Asia. Regarding DTU's strategic international alliances, the department has enforced its collaboration with KAIST and the EuroTech partners.

On innovation and science based consultancy the department sells its software based on the research internationally and receives experience and income, which finances continuous development and supporting research. We lead, and contribute to, several international standards groups under CENELEC and IEC and participate in the IEA wind activities. We have international projects and global collaboration with public institutions in e.g. South Africa, China and India and participate in several wind resource mapping projects as part of the World Bank's ESMAP program.

Within education, DTU Wind Energy offers a complete two-year master programme in wind energy with predominantly international students. Furthermore, DTU Wind Energy participates in the Erasmus Mundus European Wind Energy Master (EWEM), a two-year double-degree programme in cooperation with NTNU in Norway, University of Delft in the Netherlands and University of Oldenburg in Germany. The PhD school takes in approximately 15 new students every year, and the majority of students in the master programmes and the PhD-school are international.

1 IRENA report Renewable Power Generation Costs in 2014

The department's international profile was illustrated by arranging and hosting several international conferences and symposia in 2014. DTU's Annual International Energy Report 2014 and the associated conference focused on wind energy with a strong involvement of not only DTU Wind energy, but several other departments at DTU as well at key stakeholders from the sector in Europe and internationally. Among other things the report pointed to the need for larger wind turbines, lighter materials and far more cost-efficient wind turbines, but also stated the sometimes overlooked fact that wind energy generated in areas with good wind conditions, e.g. coastal areas, can now compete with fossil fuel-based energy.

To be an attractive partner internationally requires not only strong technical-scientific competences, but also a leading research and test infrastructure. In 2013 the department invested in the large PC cluster for advanced modelling, simulations and scientific computing together with AIT and DTU MEK. In 2014 this has been used intensely in good collaboration with DTU MEK. At the National Test Centre for Large Wind Turbines in Østerild, a very important milestone was reached as the last test stands were rented to industry. The DTU Wind Energy test fields will now host prototype wind turbines from Danish, German, French and Chines companies. The first phase of establishing the national WindScanner Research infrastructure was concluded in 2014 and important steps were taken in the development of an ESFRI European WindScanner Facility. A rotating aerodynamic test rig and an X-ray tomography system funded by the Villum Foundation were also installed in 2014. A new 850 kW research turbine was procured and important milestones in the development of a national wind tunnel for wind energy applications were reached.

Research is, nonetheless, the core activity and takes its lead in critical challenges, the need for development and application of wind energy technology. As such the research is cross disciplinary and the research programmes include critical basic science such as fluid mechanics, boundary layer meteorology and material science, wind turbine technology issues and wind energy systems issues such as wind resources and siting, offshore and control and integration of wind energy plants. The research is mostly technical, but also includes economic and social issues in cooperation with among others DTU Management Engineering.

A key effort in our innovation effort was initiated in 2014, where the department together with DTU AIS - and cofounded by The Danish Industry Foundation - decided to make a sector analysis “Development of component and sub suppliers in the Danish wind turbine industry”. For many years the main industrial collaboration has been with the major wind turbine manufacturers, so this project focuses on strengthening the relationship between the research community at DTU and the industry, including specifically the component and sub suppliers.

At the end of 2014 the Department comprised 238 employees from 38 different nations. The department welcomed 15 new PhD-students, while 17 submitted their PhD.

As the following pages testify, 2014 was a year with much international cooperation and new research results and activities. It is my hope that this annual report can be used as an introduction to a department with an exciting multi-faceted research programme in a broad national and international cooperation and with a similarly strong effort on value creation through education, innovation and science-based consultancy. Hopefully, it will inspire present and potential new partners to cooperate with DTU Wind Energy for the development of the wind energy sector.

HIGHLIGHTS

January
Acoustic Day
24 January DTU Wind Energy held a one day conference: the 'Wind Turbine Acoustic Day'. It was an interesting day where people from the industry and other interested persons participated. An overview of the current status of the scientific knowledge on wind turbine acoustics and noise was presented.

Furthermore, other topics like the social impact of wind turbine noise and planning issues and tools were presented.

January
Inaugurational speech
Head of Section, Dorte Juul Jensen, held her inaugurational professor speech at DTU with the title: 'Perspectives on 3D characterization, analysis and applications of metals'. In her speech she presented the many possibilities of changing the interior microstructure and thus the properties and performances of a metal. She gave examples of applications and an outlook on key research issues within this field for the future.

February
Strategy meeting with President, Anders Bjarklev at Risø Campus
DTU's president, Anders Bjarklev visisted the Department of Wind Energy at Campus Risø and presented DTU's strategy for 2014-2019.

Anders Bjarklev mentioned several topics and commented on DTU's mission, vision and values: credibility, engagement and innovation.

He emphasised that DTU Wind Energy is a strong research department – also seen from an international perspective.

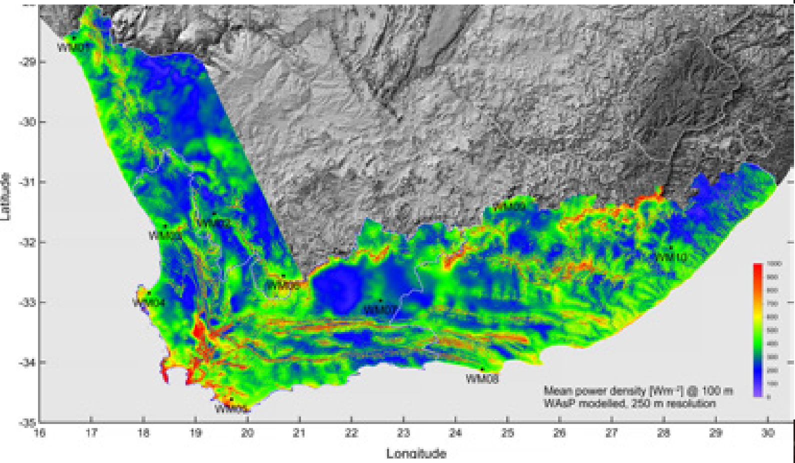
March
Inauguration of the new PC cluster
18 March DTU inaugurated the recently purchased Computer Cluster for high-performance computing within computational fluid dynamics, fluid structure interaction and structural optimization. At the official opening, DTU's President Anders Bjarklev and mayor of Roskilde, Joy Mogensen cut the red ribbon, held by Head of Department Peter Hauge Madsen.

March

2014 Innovation Award from JEC in the Sustainability category

Professor Povl Brøndsted (left with the red tie) won the JEC Innovation Award 2014 in the category "Sustainability" together with Siemens Wind Power, 3B Fibreglass and DSM for the development of a new composite material based on a polymer matrix that is styrene-free and 40% bio-based.

The award was given at the JEC conference in Paris, 11-13 March.



April

Wind Atlas in South Africa finalized

The finalization of the Wind Atlas for South Africa (WASA) Project for the Western Cape and parts of the Northern and Eastern Cape marked an important milestone in South Africa's renewable energy efforts. WASA is implemented as a research and capacity building project with SANEDI as the Executing Agency and the Implementation partners are: CSIR, SAWS, UCT (CSAG) and DTU Wind Energy.

May

DAMVAD Conference

19 May the conference about Wind Energy Research Strongholds as basis for growth was held at The National Museum of Denmark.

DTU's president, Anders Bjarklev introduced the day by talking about Denmark's business and research stronghold within the wind energy sector. During the day, concerns about the future were discussed and expressed due to increased international competition and global investments in this sector and the fact that funding in Denmark has decreased.

May

Senior researcher Mathias Stolpe from DTU Wind Energy was promoted Dr. Techn. for his thesis with the title:"Models and Methods for Structural Topology Optimization with Discrete Design Variables". The diploma for his achievement was handed over at DTU's Annual Commemoration Day in May.

June

Torque Conference

The conference entitled Torque 2014, was held at DTU in Lyngby 17-20 June.

The fifth Science of Making Torque from Wind Conference was organized by DTU Wind Energy and the European Academy of Wind Energy.

It was the largest Torque conference ever held with 322 participants and 186 peer-reviewed papers about anything from aerodynamics of wind turbine rotor to flow over the natural terrain.

June

Inauguration of the rotating test rig site at DTU Risø Campus

26 June the project INDUFLAP inaugurated the rotating test rig site at DTU Campus Risø.

The inaguration took place at the row of wind turbines and participants could take a closer look at the test rig and prototype flaps.

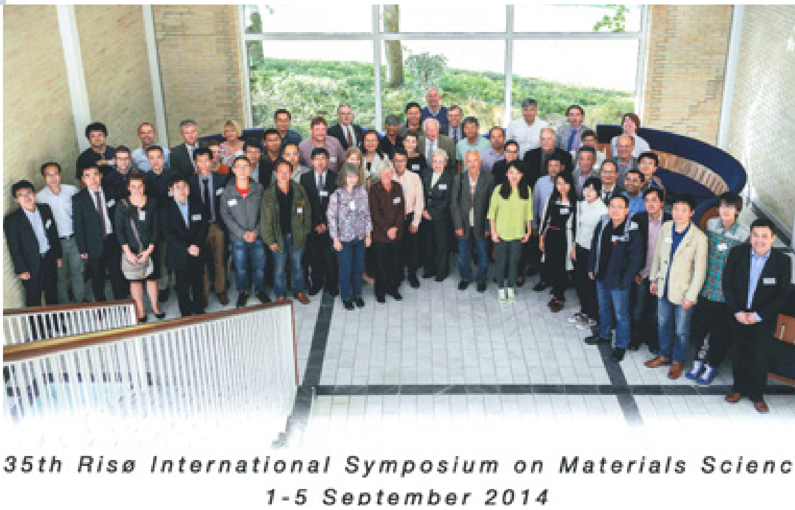
The rotating tests have served as proof of the concept of the flap system working on operational loading corresponding to full scale conditions on a MW turbine.

September

Risø International Symposium on Material Science

The Risø International Symposium on Materials Science 2014 from 1 - 5 September at DTU Campus Risø – Department of Wind Energy, Niels Bohr Auditorium.

The main subject at the conference was New Frontiers of Nanometals.



September

Staff Conference for DTU Wind Energy employees

This year the Department of DTU Wind Energy held its Staff Conference at Konventum in Helsingør.

Head of Department, Peter Hauge welcomed all employees and was followed by musician Peter Bastian who gave a speech about recognition, acknowledgement and feedback in a multicultural context. Other interesting topics were: efficient and meaningful meetings, The power of attitude – It might get Loud.

A couple of interesting days for the staff both professionally and socially.

September

10th European Fluid Mechanics Conference

The 10th Euromech Fluid Mechanics Conference was held at the DTU from 14 to 18 September.

The conference aims at covering the whole field of Fluid Dynamics, comprising from most fundamental aspects to recent applications. It provides a world-wide forum for scientists to meet and exchange information of all areas about fluid mechanics.

November

The Wind Day

The Wind Day was held at DTU Risø Campus with 170 participants, 1 November.

DTU Wind Energy presented a part of its activities and other presentations given were about extending the lifetime of wind turbines, and there were presentations by The Danish Cancer Society, Rigshospitalet, the Environmental Protection Agency and Grotmij and also and topics concerning wind turbines economy and taxation presented by the Danish Ministry of Taxation and the Ea Energy Analyses.

November

DTU International Energy Report meeting

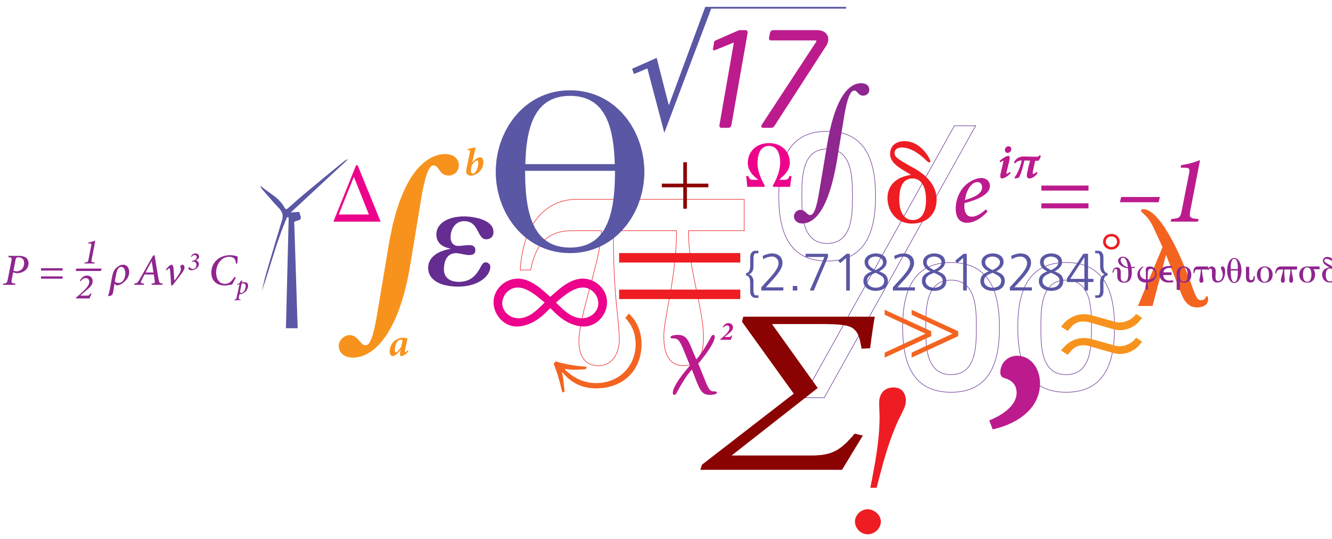
DTU's annual energy report focused on wind energy. The market is growing, but there is a need for technological development, more recycling and strong support from the authorities to achieve the objectives of increasing wind power's share of the total energy supply which was stressed during the conference.

November

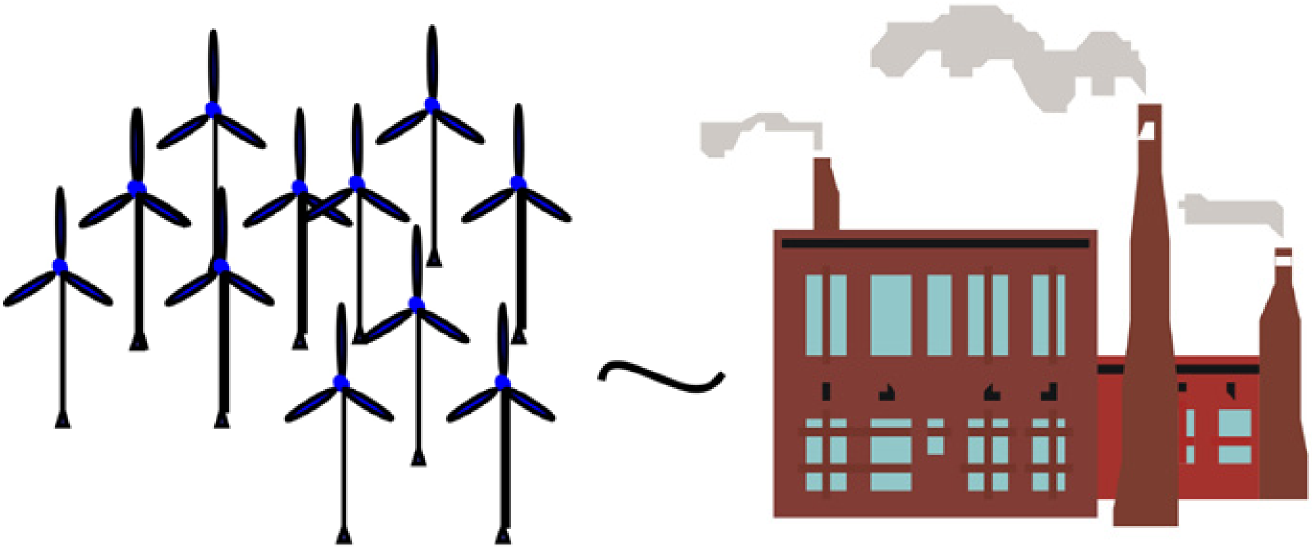
WindScanner Day

In November WindScanner day was held at Risø Campus to mark the event that the Danish National WindScanner Research infrastructure facility, WindScanner.dk is now established and has become an asset for researchers and industry.

Interesting results and achievements obtained with the research facility were presented. All delegates were invited to participate in an open forum panel discussion about the research infrastructure's further development and national and international implementation plans.



ANCILLARY SERVICES



Research and development of a grid friendly wind power technology has a high priority at DTU Wind Energy. We have been leading and contributing to a significant portfolio of projects in this area in cooperation with other universities and with the grid operators and wind energy industry end users. In 2014 we reached milestones which contribute to position DTU Wind Energy in an internationally leading role regarding research and development of ancillary services from wind power plants.

The recent explosive development of wind energy – exemplified by the new record of 39 percent of Denmark's electricity covered by wind power in 2014 – makes wind energy a key technology in the development of future sustainable power systems. However this development also calls for more grid friendly wind power plants in order to ensure a stable operation of future power systems.

The power system stability is ensured by ancillary services which are provided by power plants in addition to the power production. This includes power reserves ensuring that the production can be balanced with the consumption at any time, and enhanced services which are technical characteristics embedded in conventional power plants.

The EASEWIND project funded by the ForskEL program and managed by Vestas was finalized in 2014. Senior researcher, Anca D. Hansen managed the EASEWIND research on development and model based validation of enhanced ancillary services for wind power plants. This line of work is continued in the RePlan Plan project will investigate the coordinated provision of ancillary services from wind and PV.

The EU ReservicES project supported by Intelligent Energy Europe program and lead by EWEA was also finalized in 2014. This project reviewed the needs for ancillary services and the technical capabilities of wind and PV to provide the services. Senior researcher Nicolaos A. Cutululis was managing the survey of technical capabilities of wind power and identification of gaps in the ReservicES project.

In addition to those projects, 3 PhD students enrolled at DTU Wind Energy worked with ancillary services in 2014. Lorenzo Zeni, DONG Energy Wind, will finish his PhD in 2015 with studies of ancillary services from offshore wind power plants connected to High Voltage Direct Current (HVDC) transmission systems. This line of work is continuing with PhD student Jayachrandra N. Sakamuri, who started in 2014. Finally, Abdul Basit will defend his PhD with focus on automatic reserves provided by wind power plants in 2015.

Our research on ancillary services has been disseminated at academic conferences and in journals, and on top of that, Poul Sørensen was invited to present this topic in five industrial conferences, including chairing of Wind Power Monthly's Grid Support and Ancillary Service Forum in June.

By Poul Sørensen, Anca D. Hansen and Nicolaos A. Cutululis

CARBON/GLASS HYBRID COMPOSITES – BLADE KING

Considering the specific market demands related to technology, the wind turbine market is demanding longer and lighter blades to be able to increase the annual energy production and to reduce the mass driven loads. The use of carbon fibres together with glass fibres as reinforcement in hybrid composite blades is an efficient way to reduce the mass and increase the length of the blades – especially as upgrades for existing wind turbine platforms.

The Blade King project was initiated in 2008, funded by The Danish National Advanced Technology Foundation with the overall objective to improve the production capacity, and with participation of LM Wind Power, Comfil, Aalborg University (AAU) and DTU Wind Energy. The international financial crisis caused a significant overcapacity in the market, and consequently the project objective was redefined with focus on longer and lighter blades. Development of competitive hybrid carbon/glass fiber composite materials, new blade designs and related manufacturing concepts became the main project objectives.

Carbon/glass hybrid composites were matured based on results from test coupons. The research at DTU Wind Energy has led to detailed studies of the mechanisms of interaction between the two types of fibers and matrix in hybrid composites, in particular the importance of the way the two types of fibers are ”mixed” and of fiber misalignment, in relation both to the process technology and the mechanical properties. Unidirectional composites with different fiber mix ratios have been realized by filament winding of “dry” fibers and subsequently infusion of the matrix material. Mechanical micro models for these interactions are developed, and a method for characterization of the hybrid modes, both volumetric composition and geometric configuration, is established.

Targets for the new blade design concept were flexibility and ability to adapt to the rapidly changing market and demand for new blade variants. Test of adhesive bonded sub-components were performed at AAU. LM Wind Power performed a large scale manufacturing test of a 73.5 meter blade shell. Through a huge effort on the hybrid fabric development, with increased focus on the drapeability, it has been possible to position and consolidate the hybrid fabric in the test blade shells without creating fibre wrinkles in the laminate. The resin infusion strategies of the shells and the main laminate have also been tuned so no areas with “dry” glass/carbon fibers were detected.

To validate the new blade design and manufacturing concept a full-size 58.7 meter blade was realized in December 2014 with the hybrid fabric and vinylester vacuum infusion resin developed in the Blade King project.

By Tom Løgstrup Andersen

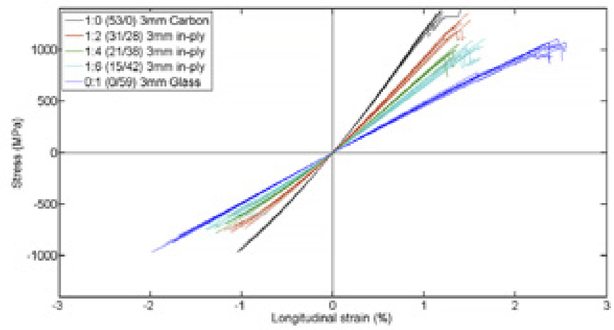


Fig. 3. Stress-strain plot of different hybrid configurations in tension and compression.

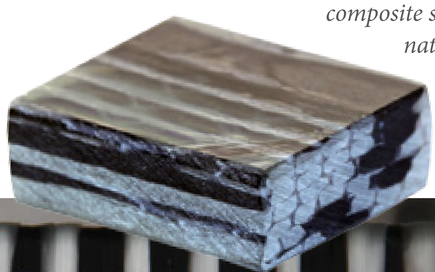


Fig. 2. Preparation of hybrid composite sample for determination of fiber content and porosity.

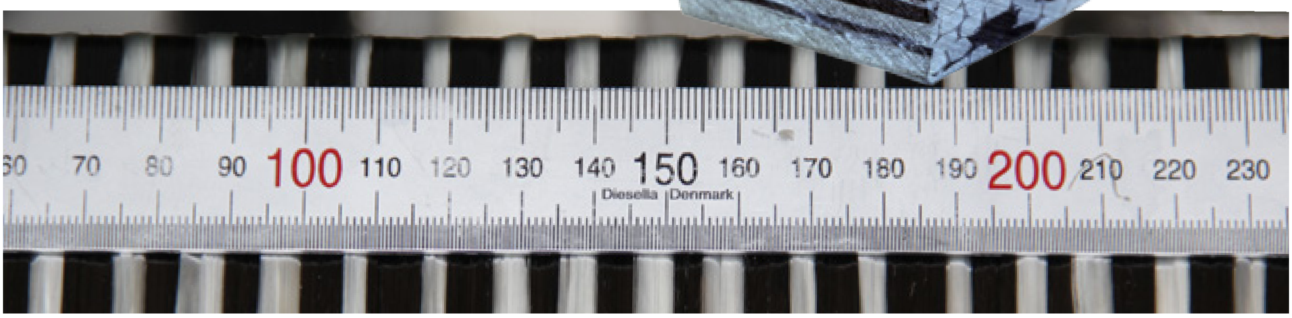


Fig. 1. Filament winding of carbon (black) and glass (white) fibers for a hybrid laminate at DTU.

MIRAS – A FAST AND ACCURATE PANEL METHOD FOR ROTOR AERODYNAMICS

MIRAS is a computational model for predicting the aerodynamic behavior of wind turbine rotors. The core solver is based on an unsteady free wake three-dimensional panel method which avoids restrictive computational costs, making its use more attractive during the design stage of a wind turbine.

The design of a wind turbine requires access to fast and accurate computing tools for predicting the aerodynamic behaviour of rotor blades. Today, design of wind turbines is carried out employing the so-called BEM (Blade-Element Momentum) technique, which is a simplified approach that is extensively used by the industry. The BEM technique is based on one-dimensional momentum theory and requires a considerable amount of engineering add-ons to take into account complex flow conditions, such as yaw or wind shear. MIRAS is based on a viscous-inviscid interactive approach, which makes it possible to take into account such conditions as an intrinsic part of the flow solver, hence reducing the amount of engineering approximations during the design phase of a wind turbine. Due to the increase in computer capacity, MIRAS has the potential to become an alternative between the fast, but simple, BEM method and heavy, but more accurate, Navier-Stokes solvers.

During the last seven years a strong effort has been made at DTU-FLU to develop a wide variety of viscous-inviscid interaction methods. Originally, the work concerned two-dimensional flow solvers for airfoil calculations, including steady, unsteady and deep stall simulations. Moreover, in the last three years, the three-dimensional solver MIRAS has been developed, now making possible the simulation of flows around a wind turbine using the panel approach.

Opposed to most of the computer tools based on the panel method technique, MIRAS, has been conceived to take into account friction effects inherent to the near wall region, or boundary layer, which plays a crucial role in the aerodynamic behaviour of the rotor blades. This is accomplished using a viscous-inviscid coupling, through the transpiration velocity concept, which is capable of mimicking the effect of the boundary layer into the outer potential flow.

Recently, MIRAS has been coupled with FLEX5 which models the dynamic behaviour of wind turbines. This coupling enables MIRAS to perform interactive aero-elastic simulation, which in the near future will be used as a platform for blade design and optimization.

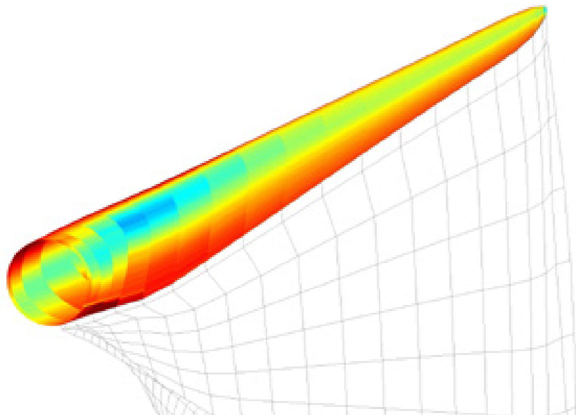


Fig. 1. Blade surface pressure distribution and near wake geometry during MIRAS simulation.

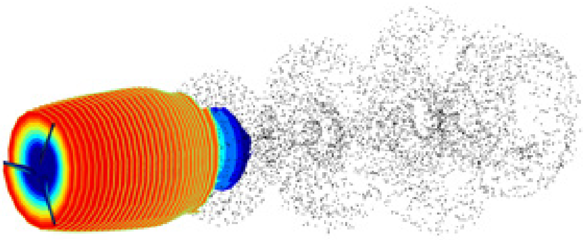


Fig. 3. MIRAS simulation of the flow past the NTNU model rotor at $\lambda = 12$ in Vortex Ring State.

Presently, the code includes new modules to handle wind shear as well as inflow turbulence. As part of the international cooperation project AVATAR, the new capabilities of the code will be further developed and validated during the next four years.

By Néstor Ramos García

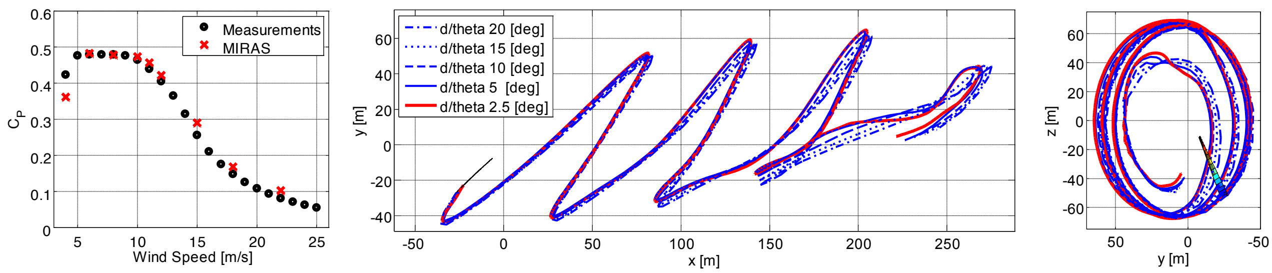


Fig. 2. Left - NM80 turbine power curve. Center and right – Convergence study on the NREL 5MW virtual rotor in yawed flow.

OPTIMAL DESIGN OF BUCKET FOUNDATIONS

Structural optimization is a collection of techniques for systematic design of load carrying structures. It has been successfully applied to propose new design concepts and significantly reduce the mass of heavy parts of Bucket Foundations.

The foundation of an offshore wind turbine, which is the structure reaching from the lower end of the tower down to the seabed, constitutes a large part of the total costs. The Bucket Foundation illustrated in Figure 1 is developed by Universal Foundation A/S owned by Fred Olsen from Norway and is a design concept that can potentially reduce the cost of energy for offshore wind farms in both shallow and deep waters. DTU Wind Energy has together with Universal Foundation A/S developed techniques for structural optimization of the knee stiffeners of the bucket lid which constitute a large part of the structural mass and thus the cost. This research work is part of the project "Cost-effective mass production of Universal Foundations for large offshore wind parks" which is funded by the Danish National Advanced Technology Foundation. The project aims to move the Bucket Foundation from a research, development, and demonstration phase into commercialization and industrialization.

The specific objective of this research work is to reduce the cost of energy by reducing the mass of the knees through structural optimization. This is done by adapting structural topology optimization which is a powerful technique for conceptual optimal design. The topology optimization problems are solved using the commercial optimization software called Tosca Structure coupled with the commercial finite element software called Abaqus for the structural analysis. The model of the foundation shown in Fig. 2 is loaded with gravity loads as well as extreme static horizontal forces and moments at the top of the shaft. The initial knee design is illustrated in Fig. 2. The topology optimization problem is formulated with the objective to minimize the structure's compliance, i.e. maximizing structural stiffness, given a mass constraint, see Fig. 3a. The results from topology optimization shown in Fig. 3b are then interpreted and used as a basis for the final design taking into account buckling, manufacturability, and mass production. Results from topology optimization have led to the new design concept shown in Fig. 4 which reduces the mass of the stiffeners by 25%. This corresponds to a weight reduction of 1.25 tons pr. knee or almost 19 tons per foundation.

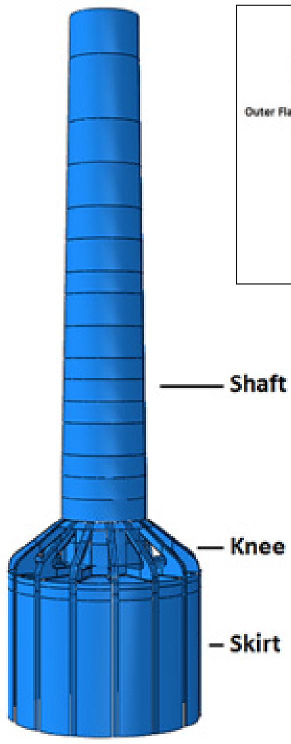


Fig. 1. Illustration of the Bucket Foundation.

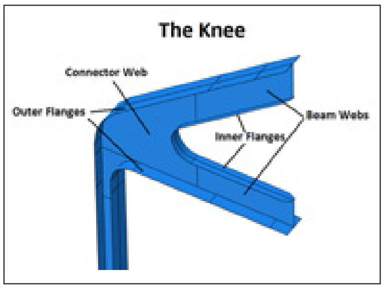


Fig. 2. The initial design of the knee.

By Mathias Stolpe, William T. Courtney, Robert Bitsche and Thomas Buhl

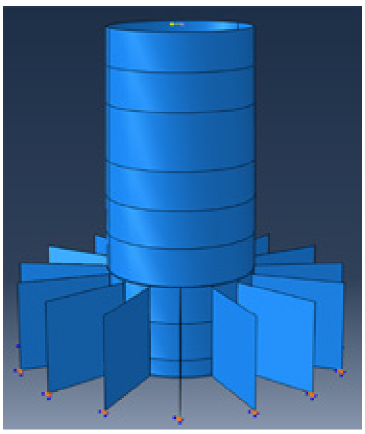


Fig. 3a. The design domain for topology optimization.

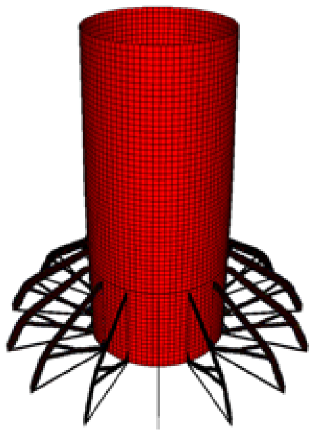


Fig. 3b. The results from topology optimization.

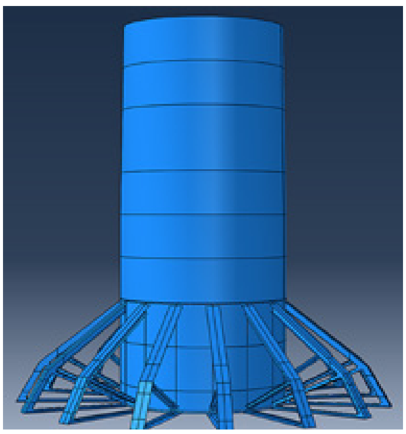


Fig. 4. The new design concept.

VORTEX GENERATORS

Vortex generators are aerodynamic devices that can improve the aerodynamic performance and potentially increase the annual energy production of wind turbines by several percent. During 2014 a breakthrough has been obtained in the prediction of airfoils using vortex generators.

Wind turbine rotors can experience separated flows that for modern machines are undesired. Separated flow can appear both close to the hub and at the outer part of the blades. This leads to a reduction of power and sometimes this reduction is in the order of several percent.

One solution to these problems is the application of vortex generators, which when designed, scaled and positioned correctly on a wing or blade can delay the flow separation. An example of two pairs of vortex generators is shown in Fig. 1.

This device has been known for decades and is e.g. used on airplane wings. However, the performance of airfoils with vortex generators mounted to the surface has mainly been investigated through costly wind tunnel tests. In 2014 we had a breakthrough concerning the prediction of the performance of airfoils mounted with vortex generators in projects together with Vestas, Envision and the company, Power Curve.

A simple and time efficient simulation model was formulated and implemented. The model uses airfoil characteristics where no aerodynamic devices are mounted and a few additional input parameters. The method was calibrated on a series of wind tunnel tests of airfoils equipped with vortex generators, and afterwards validated showing good agreement with other measurements.

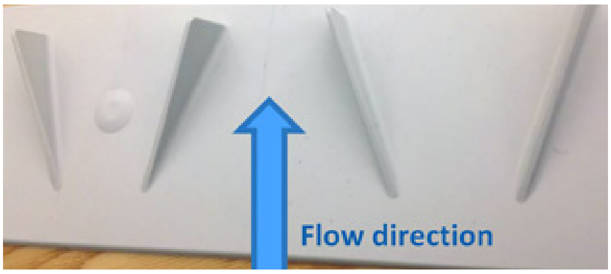


Fig. 1. Two pairs of vortex generators to be mounted at an airfoil.

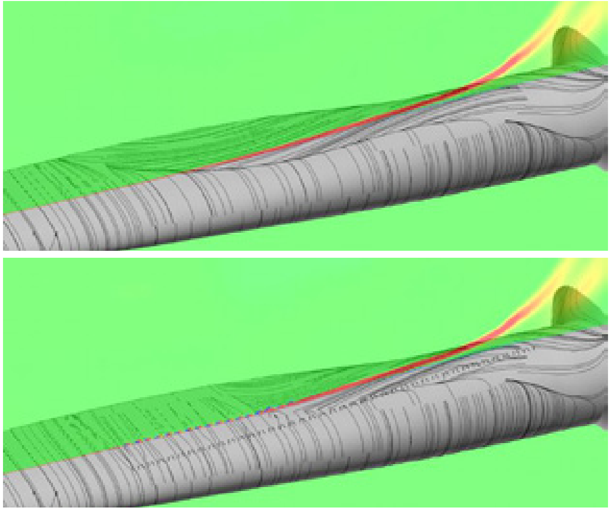
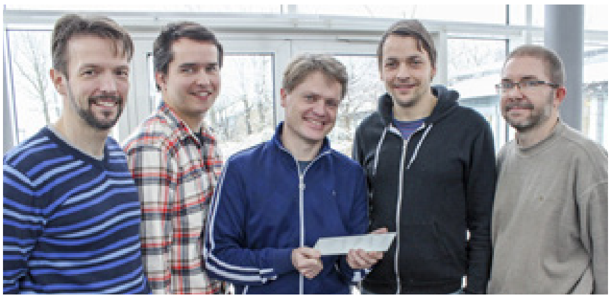


Fig. 2. Flow over a blade. Top: Without vortex generators, Bottom: With vortex generators

Additionally, advanced modeling of airfoils including vortex generators were pursued using the Computational Fluid Dynamics (CFD) tool, EllipSys, directly resolving the geometry of the vortex generator. Comparing these simulations to wind tunnel tests showed very good agreement. Inspired by this, a more computationally efficient vortex generator model was implemented into EllipSys based on the so-called BAY model. This approach reduces the computational time significantly compared to the method where the vortex generators are fully resolved. Fig. 2 shows an example of the flow field at the inner part a rotating rotor blade with and without a row of vortex generators. The vortex generators are clearly capable of suppressing separation over a significant part of the blade span.

Both the engineering vortex generator model and the BAY based CFD model ensures that full rotor simulations can be carried out. This is an important step in our simulation capabilities so that the inclusion of the vortex generators can be used directly in airfoil and blade design. For more information see [1,2]

By Mac Gaunaa, Witold Skrzypinski, Christian Bak, Niels Troldborg, Niels N. Sørensen and Frederik Zahle



From the left: Mac Gaunaa, Witold Skrzypinski, Christian Bak, Niels Troldborg, Niels N. Sørensen.

1 Skrzypinski,W.R.; Gaunaa,M.; Bak,C., The Effect of Mounting Vortex Generators on the DTU 10MW Reference Wind Turbine Blade., Journal of Physics: Conference Series (Online), Vol. 524, No. 1, 012034, 2014.

2 Troldborg,N., Zahle,F., Sørensen,N.N., Simulation of a MW rotor equipped with vortex generators using CFD and an actuator shape model, American Institute of Aeronautics and Astronautics, 53rd meeting 5 - 9 January 2015, Kissimmee, Florida, AIAA Science and Technology Forum and Exposition

WORLD FIRST AS CANADIAN WINDEEE WIND DOME DEPLOYS DTU WINDSCANNER

DTU Wind Energy's collaborators in Canada at The WindEEE Research Institute at the University of Ontario, Canada, hosts the world's first hexagonal wind tunnel the Wind Engineering, Energy and Environment (WindEEE) Dome. It is a large- scale structure (25 meters diameter for the inner dome and 40 meters diameter for the outer return dome) able to perform scaled wind simulations over extended areas and complex terrain.

In September DTU and WindEEE jointly confirmed the successful installation of a DTU Wind Energy developed short-range WindScanner to study tornados as well as wind and turbulence effects inside the dome for wind turbines, buildings and structures.

DTU Wind Energy and University of Ontario, Canada believe this to be the first deployment of its kind, utilizing the 'best in class' of both 3D wind-system generating wind dome, WindEEE, and a wind lidar measurement sensor, a ZephIR technology based steerable beam scanning WindScanner.

DTU Wind Energy collaborator, Professor Horia Hangan, Director of the WindEEE Research Institute at Western University, Canada says: "WindEEE, our tornado generating wind dome is now home to the world's leading measurement system, the DTU WindScanner which is based on equally novel ZephIR wind lidar technology and a DTU Wind Energy patented wind lidar scanning system".

DTU Wind Energy's Canadian collaborators chose to equip their WindEEE dome with WindScanner's remote sensing wind measurement methodology due to the WindScanner systems' high speed, high resolution syncronized beam steering and scanning systems able to provide detailed full-scale real atmospheric wind and turbulence measurements, cf. www.windscanner.dk.

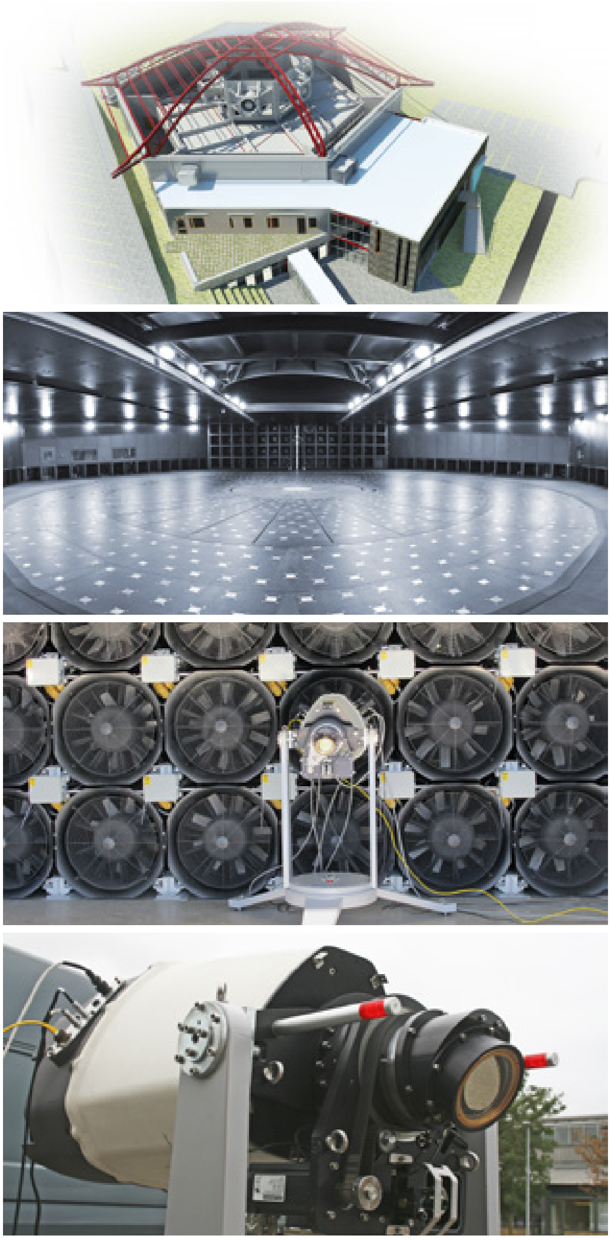
The first of three space and time syncronized short-range WindScanner systems required to measure 3D wind fields inside the WindEEE dome was installed in the WindEEE Dome in September.

This overseas collaboration now combines today's state-of-the-art technologies regarding scaled wind tunnel measurements to help researchers and industry to understand more about the vulnerability to turbulence of wind turbines, wind farms, and other buildings and structures.

With increasing rotor diameters of wind turbines the turbulent effects produced become increasingly significant in the operations, maintenance and performance of modern wind farms.

Via overseas collaboration, WindEEE and DTU Wind Energy in collaboration with assistance from industry partners from ZephIRLidar in the U.K. and Danish IPU we are now prepared to face today's wind engineering and wind energy challenges head-on. With the combined wind dome and WindScanner-based remote sensing wind field scanning methodology another step has been attained towards future quantum leaps in wind engineering and wind energy research.

By Torben Mikkelsen



From Top: 1) WindEEE facility in Ontario, Canada 2) Inside the WindEEE facility where DTU WindScanner is installed 3) DTU WindScanner installed in front of one of the fan arrays 4) Close-up of the DTU Wind Energy WindScanner scan head.

Photo showing WASA project mast (WM08) at near Humansdorp, Eastern Cape, South Africa.

WIND ATLAS FOR SOUTH AFRICA

The Wind Atlas for South Africa showcases the most recent developments in the application of numerical wind resource modelling techniques and tools with an unprecedented field measurement programme for verification of results. The project has raised the bar for mapping of wind resources and wind conditions internationally and made all results available in the public domain with full transparency regarding methods.

The Wind Atlas for South Africa (WASA) project was completed in 2014 with workshops in March attended by more than 150 participants from the public and private sector, and received significant media attention. The project outputs are the result of the most recent techniques within the Wind Atlas Method, developed at DTU Wind Energy since the 1980s. The project was mentioned in many press articles and in speeches by the Danish ambassador to South Africa and the UN resident representative, as well as by South African and Danish ministers at the annual wind energy conference, Windaba 2014.

The WASA project is headed by the South African Department of Energy and funded by the UNDP-GEF and Denmark. The project has been executed by South African National Energy Development Institute (SANEDI) coordinating and contracting contributions from the implementing partners: CSIR, UCT, SAWS, and DTU Wind Energy.

DTU Wind Energy has been a main partner and provided the methods for calculating wind and extreme wind atlases. Numerical weather prediction and climate modelling tools have evolved rapidly in recent years and the DTU researches in opportunities for their application in wind energy. The cooperation between the WASA partners has made the success of the project possible. The full transparency of the approach as well as the availability of all results in the form of data, guidelines, presentations and reports in the public domain have made the project pioneering and unique.

The WASA project has made a significant number of ground-breaking developments in wind mapping, namely:

- The first WRF-based Numerical Wind Atlas – based on a new generalization method for simulated wind time series generated by the open source Weather Research and Forecasting (WRF) mesoscale model.
- The first high-resolution Wind Resource Map – applying a new automated microscale modelling approach for running WAsP in large geographical areas and thereby obtaining a surface wind map for the entire project domain.
- The first Extreme Wind Atlas for South Africa, based on two newly developed and published methods. One of the methods uses mesoscale modelling for storms and the other method uses global model data and statistical downscaling.

READ MORE HERE
www.wasa.csir.co.za and
www.wasaproject.info

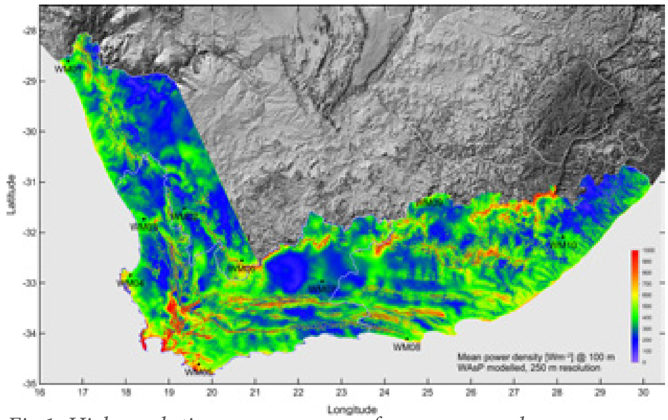


Fig.1. High resolution resource map of mean power density [W/m²] at 100 m above ground level with 250 m grid spacing.

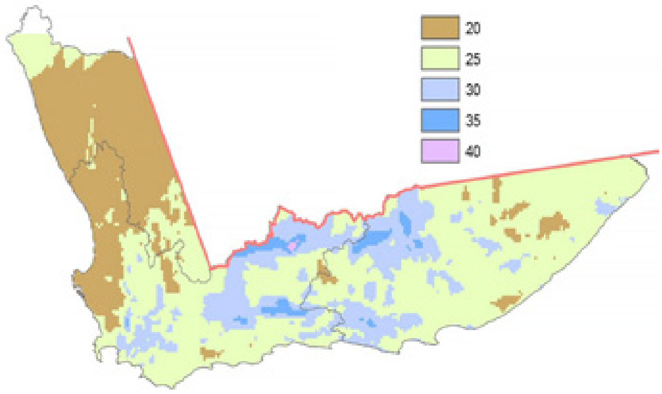


Fig. 2. 1:50 year 10-minute wind speed (m/s) for standard condition (10 m above ground level, flat terrain and roughness length 5 cm). The values are ready to be used in WEng to obtain the site-specific estimates. The map is recommended to be used for relevant estimate of IEC standard for South Africa.

The WASA project has already been used as a reference for specification of the World Bank ESMAP Renewable Energy Mapping programme. It is also a model project featured in the IRENA (International Renewable Energy Agency) Global Atlas of renewable energy resources. Furthermore, the WASA project has already been applied for the Strategic Energy Assessment and planning by the South African authorities and for that received a letter of congratulations from the South African Wind Energy Association.

By Jens Carsten Hansen, Andrea Hahmann, Niels G. Mortensen, Xiaoli Larsen, Jake Badger, Mark Kelly and Patrick Volker

Fig. 1: Picture of the interior of the Zeiss Xradia 520 tomography equipment at DTU Wind Energy and Søren Fæster aligning a sample.

X-RAY COMPUTED TOMOGRAPHY

A donation from the Villum Foundation has made it possible to perform advanced X-ray computed tomography at DTU Wind Energy.

X-ray computed tomography (CT) is a non-destructive technique that provides 3D images of the internal structures of materials. The technique is ideal for characterizing materials, observing fracture and for in-situ investigations of the microstructural evolution during heating, cooling, oxidation, tension, compression, etc. X-ray tomography offers non-destructive views into deeply buried microstructures that cannot be observed with 2D imaging techniques, such as optical microscopy, SEM and TEM.

When X-rays are passing through a material the X-rays can be absorbed or scattered. The X-ray attenuation coefficient is material specific and this makes it possible to distinguish between different materials in an X-ray image, like in medical X-ray imaging where bone and tissue can be distinguished.

The tomography equipment at DTU Wind Energy, a Zeiss Xradia 520, is equipped with a set of different objectives which enables reconstructions in 3D with different resolutions from tens of micrometers down to less than 1 micrometer. The instrument is thus very versatile and capable of studying a wide range of materials and scientific/technical problems. By combining 3D X-ray tomography with mechanical loading, unique information of the three dimensional damage evolution can be obtained. At present, a sample deformation stage is available by which the sample can be deformed in tension and compression up to 5kN at temperatures from -20°C to +160°C. The tomography equipment is located next to a collection of advanced mechanical testing equipment, so stepwise testing and repeated tomography scanning is also available. Furthermore, it is planned to develop novel in-situ testing equipments in order to study 3D microscale deformation, damage and failure processes at different load cases.

Diffraction contract tomography is a technique that makes it possible to make 3D reconstructions of the sample crystallography. This technique was developed using synchrotron radiation by scientists in the former Materials Research Division at Risø

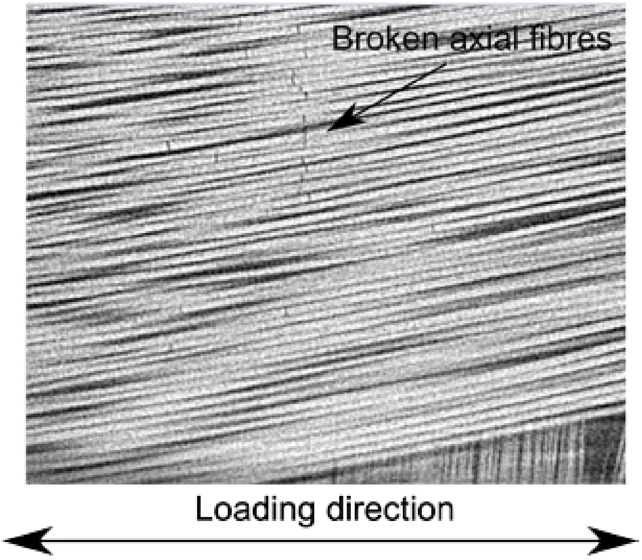


Fig. 2. A reconstructed cross-section through a glass fibre composite sample (a wind turbine blade material) which has experienced cyclic loading. As can be seen, some of the load carrying fibres are broken. The studies of internal damage over time will contribute to the development of more fatigue resistant materials and to design longer wind turbine rotor blades.

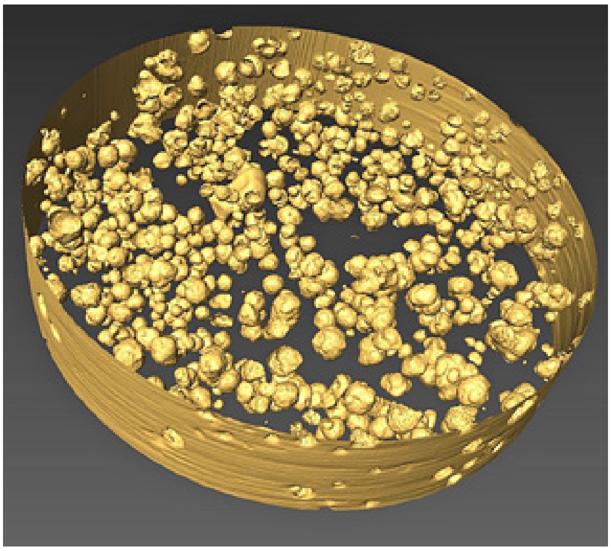


Fig. 3. A 3D reconstruction of spherical graphite cast iron. The sample diameter is 2 mm marked by the outer ring. The graphite nodules are characterized by the X-rays and visualized above. Failure initiation and propagation at and around different types of graphite nodules can be studied by in-situ loading of the specimen.

DTU (now they are in the DTU Wind Energy, Physics and Energy Conversion Departments) and has recently been implemented on laboratory tomography equipments by the company Xnovo Technology which is a DTU spin out company. The development of diffraction contract tomography will continue at DTU where this software is available as one of only two places in the world. The tomography equipment is donated by the Villum Foundation and is within the DTU Center for Advanced Structural and Materials Testing which is an experimental research facility for advanced mechanical testing of structures and materials.

The X-ray tomography instrument will be used for investigating metallic samples with focus on crack initiation and propagation, particle distributions, hydrogen embrittlement, martensite formation, white etched areas (WEA) and other relevant material problems for the metallic components in wind turbines. In-situ observations of the evolution of microscale failure mechanisms is extremely valuable for fibre composite materials, which can fail by a number of complicated interacting failure mechanisms; in-situ observations in 3D make it possible to establish better micromechanical models in the future. The laboratory X-ray tomography equipment at DTU Wind Energy is thus a very valuable new tool for investigating and improving materials as well as for developing new materials for wind turbines.

By Søren Fæster and Dorte Juul Jensen

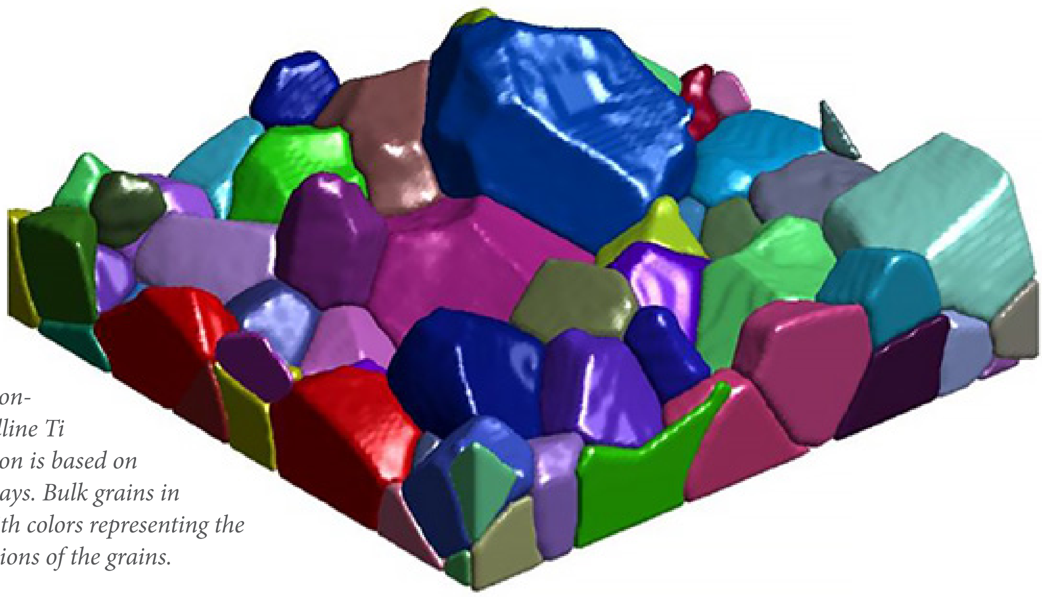


Fig. 4. A diffraction contract tomography reconstruction of a polycrystalline Ti sample. The reconstruction is based on the diffraction of the X-rays. Bulk grains in the sample are shown with colors representing the crystallographic orientations of the grains.

REWIND : KNOWLEDGE BASED ENGINEERING FOR IMPROVED RELIABILITY OF CRITICAL WIND TURBINE COMPONENTS

REWIND is a Danish Strategic Research Council (DSF) funded center to perform strategic research at the highest level in the field of materials-manufacturing-properties-performance of metallic components in the drivetrain of large wind turbines, with the ultimate aim of enhancing the reliability, extending the lifetime and arriving at an improved life expectancy prediction of such components.

The center is led by DTU, Dept. of Mechanical Engineering and the project participants constitute leading experts from DTU Wind Energy, Aalborg University, DONG Energy, Vattenfall, Global Castings, as well as other international partners including Magma Gmbh, Helmholtz-Zentrum für Materialien und Energie from Germany and Michigan State University from the United States.

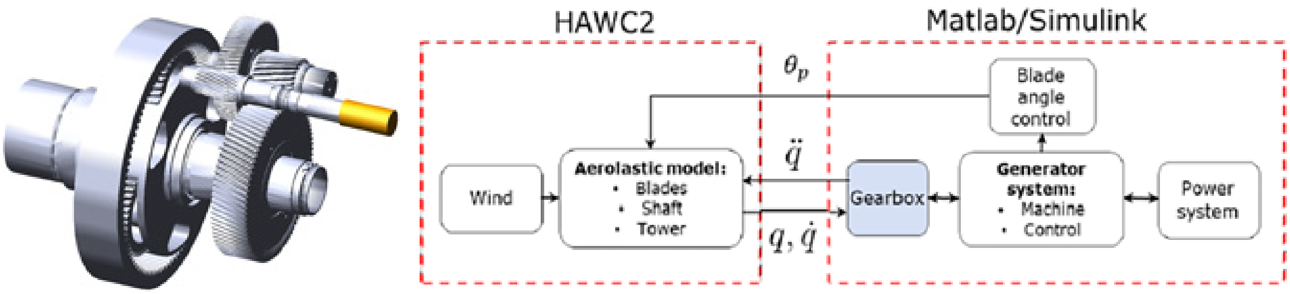


Fig. 1. Electro-mechanical modeling of the drivetrain to simulate its constituent loads in different operating conditions.

The main scientific deliverables of the center are:

- A detailed evaluation of failure mechanisms in bearings and gears in relation to manufacturing and loading history.
- Establishing the basis for reliability and life time criteria and to evolve background knowledge.
- Improved numerical models for the simulation of manufacturing of heavily loaded metallic wind turbine parts.
- Better understanding of fatigue failure evolution under rolling or sliding contacts, obtained through numerical modeling and experimental observations.
- Improved electromechanical drivetrain loads simulation software along with validation. Improved knowledge on failure mechanisms and reliability of the mechanical components of the drivetrain.
- Improved probabilistic models of defects and damage accumulation for critical components and reliability assessment.

In this inter department and multiple organization project, DTU Wind Energy leads the work packages, WP-2 (Mechanical properties and damage mechanics) and WP-5 (System Simulation and In-Service Loads).

WP-2 is focuses on the mechanical properties and damage mechanics of the metallic materials used in wind turbines. Defects and cracks have been characterized using electron microscopy and X-ray tomography. Specific focus has been on graphite nodules in thick-walled ductile cast iron produced with different casting parameters, where the shape and the size distribution of the graphite nodules have been characterized in detail. The aim of this study is to develop a novel three dimensional classification method for cast iron. X-ray tomography allows visualization of the true microstructure much faster than traditional methods and therefore has potential as quality control in the industry.

WP-5 develops a detailed electro-mechanical simulation model of the drivetrain that includes all components between the wind turbine hub and grid, such as the main bearing, gearbox, drive-shaft, generator and converter. The model, developed in Matlab can interface with standard aeroelastic loads simulation codes such as HAWC2. The model predicts the dynamic loads acting on gear teeth, shafts and bearings as a function of time and in compliance with load cases described in the IEC 61400-1 Ed. 3 standard, which is used in the design of wind turbines. Further, the model bridges the electrical constituents of the generator and the mechanical components in an efficient and physically relevant method. Detailed mechanical models of a 5 MW gearbox have also been developed to determine key failure modes of the gearbox. The loads simulations have been validated in collaboration with the U.S. NREL Gearbox Reliability Collaboration (GRC) project, wherein NREL provided test data taken from a 750 kW gearbox on their test rig.

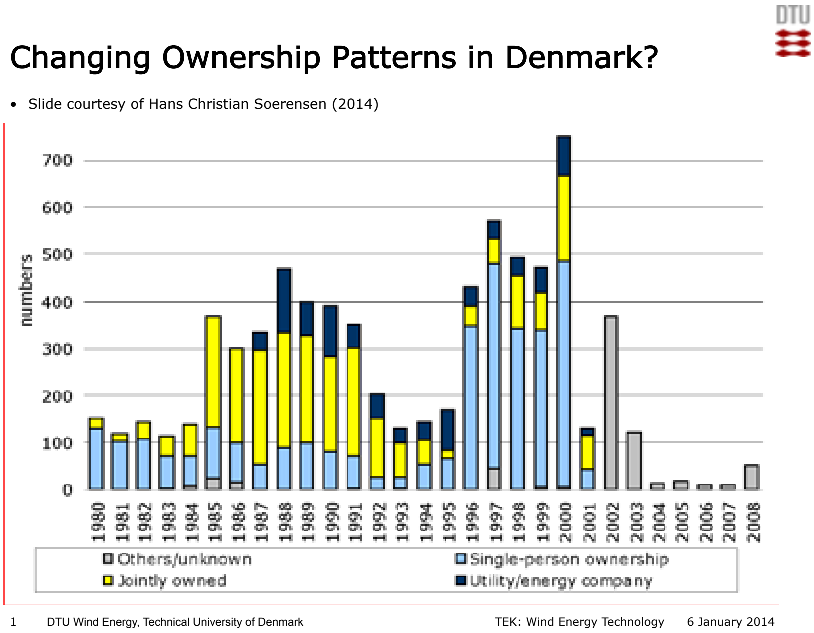
By Anand Natarajan, Søren Faester

WIND ENERGY AND SOCIETY: EXPLORING CRITICAL CHALLENGES

DTU Wind Energy is a global leader in technical-scientific competencies and helping to realize Denmark's ambitious wind energy deployment plans. Social acceptance of wind energy, however, may pose critical challenges to meeting these national energy goals and transitioning to a clean electricity system. Understanding social acceptance involves a range of social and environmental sciences which are outside of the traditional DTU Wind Energy's core capabilities. In 2014-15 DTU Wind Energy is exploring how to address these critical scientific fields related to wind and society, as more wind deployments are closer to population centers and concerns about wind turbine risks are increasingly in multi-disciplinary fields. Exploring "acceptability" of wind energy provides another opportunity for DTU Wind Energy to be a global leader.

Is the past prologue?

Denmark is a pioneering nation when it comes to clean electricity – not only as a global leader in wind installations per capita, including the first utility scale offshore plants, but also in relation to bottom-up, community ownership of wind turbines. Scientists know that a transparent planning process, effective risk communication, social trust, and equitable benefits are just a few of the important factors that can make a significant difference in the public "acceptability" of wind energy. As the height of the turbines and ownership patterns change, how will these trends affect the public perception of wind in Denmark?



More facts and figures will not solve the challenge

Educating the public may not aide in mitigating public concerns. The belief in the "deficit model" – providing more facts and figures by experts and developers may do little to persuade the public of the "right way." How shall public concerns be addressed? Studies also show that the public is quite rational, but they approach the assessment of risks in a different way than experts. People often focus on qualitative as well as quantitative measures of risk. This is a very different approach for most scientists and engineers that are typically focused on quantitative measures.

Addressing the complexities of social acceptance requires building new capacity at DTU Wind Energy

In the last 6 months, DTU Wind Energy has taken some important steps to explore this critical challenge including the following:

- A Guest Scholar was secured at DTU Wind Energy to lead the initiative. Bonnie Ram is working to identify cross-disciplinary research within Denmark and beyond.
- Working with DTU Management Engineering, the Wind Department started a new EERA Wind sub-programme on economic and social aspects. Approved in the fall of 2014, it provides an important networking platform in the Nordic region and the EU. Our Guest Scholar is now leading an initiative on public engagement strategies of wind energy involving EERA partners. DTU Wind Energy is organizing an EERA-sponsored workshop on *Public Engagement Strategies and Wind Energy* on 9 March 2015 at the Risø campus in Roskilde.
- A Danish Council for Strategic Research funded program entitled, Wind 2050, is exploring case studies of public acceptance and how developers and public sector planning processes may be more effective. A new Post-Doc position will support this program and work with the DTU Wind Energy from 2015-17.
- Linking research initiatives with education of the next generation is an important step in building new capability. For the first time, a DTU Wind planning course in January 2015 included 2 new lectures: Public Perception of Wind Energy Risks and Stakeholder Engagement Strategies
- In 2015, the Guest Scholar is arranging a lecture series with accomplished international social scientists on issues related to wind energy and society. This will expand the multi-disciplinary perspectives at the Department of Wind Energy.

By Bonnie Ram

STRUCTURAL DESIGN OF A VALIDATION ANTENNA FOR THE EUROPEAN SPACE AGENCY

Antenna measurements are important for design and for demonstration of the performance of antennas used in space as well as on earth. Such antenna measurements are often made at indoor measurement facilities equipped with a so called anechoic chamber. That is a room designed to completely absorb reflections of electromagnetic waves.

VAlidation STandard (VAST) antennas are specifically designed to monitor that different antenna measurement facilities give similar measurements of very high quality. A VAST antenna shall be designed stiff enough such that any deformities of the antenna during test, introduce an error much less than the measurement accuracy being sought. Therefore, driving requirements to VAST antennas are their mechanical stability with respect to any orientation of the antenna in the gravity field and thermal stability over a given operational temperature range.

A multi-band millimeter-wave VAST (mm-VAST) antenna has been designed in collaboration between the DTU Electro, DTU Wind Energy and the company TICRA under contract from the European Space Agency (ESA). These millimeter-wave bands, 20GHz – 50GHz, are currently being taken into use for space and mobile telecommunication applications. The mm-VAST antenna passed the critical design review at ESA on 1 December and will be manufactured at DTU in 2015.

A 3D plot of the antenna is shown in Fig. 1. The support frame and reflector are made of 8mm thick carbon fiber reinforced plastic (CFRP) panels. The feed cluster mounting interface, the antenna mounting flange and reflector mounting pins and brackets are made in Invar. These materials are chosen in order to provide the optimum combination of mechanical strength and thermal stability, as they have very low thermal expansion coefficient and high stiffness.

The antenna is modelled structurally using the commercial finite element package MSC.Patran with MSC.MARC as solver. The solid parts of the antenna are meshed with 10-noded tetrahedral elements, which have quadratic shape functions and the entire model has approximately 325.000 elements. The individual solid part of the antenna is connected via a glued contact formulation in MSC.MARC. Because of the size and the complexity of the model a computer cluster is applied to solve the analyses.

The antenna is designed to be extremely thermally and mechanically stable in the range of temperatures 20 ± 5°C under arbitrary orientation in the gravity field. The antenna has a characteristic length of approximately 500mm. In order to obtain very low measuring error, the allowable deformations of the reflector and feeds are down to 2µm. An example from the finite element analyses is shown in Fig. 2.

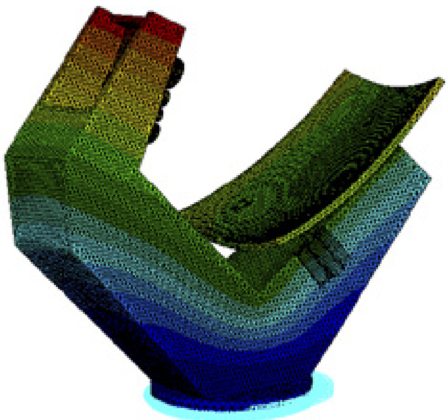


Fig. 1. The DTU-ESA mm-VAST antenna.

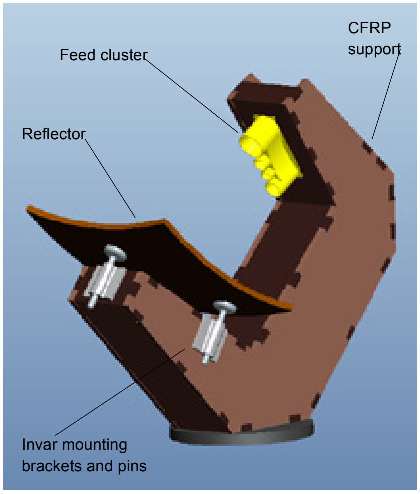


Fig. 2. Finite element analysis of gravity loading in transverse direction.

K. Branner, P. Berring, C.M. Markussen from Department of Wind Energy, Technical University of Denmark, Roskilde, Denmark

O.S. Kim, S. Pivnenko, O. Breinbjerg from Department of Electrical Engineering, Technical University of Denmark, Lyngby, Denmark

R. Jørgensen from TICRA, Copenhagen, Denmark

See phones on http://alastairphilipwiper.com/blog/radio-anechoic-chamber/.

INNOVATIVE WIND CONVERSION SYSTEMS (10 MW - 20 MW) FOR OFFSHORE APPLICATIONS

The EU FP7 funded project is an ambitious successor for the UpWind project, where the vision of a 20MW wind turbine was put forth with specific technology advances that are required to make it happen. This project builds on the results from the UpWind project and further utilizes various national projects in different European countries to accelerate the development of innovations that help realize the offshore wind turbines in the 10 MW - 20 MW range. DTU is the coordinator of this large project working with 27 European partners over a 5 year period 2012-2017.

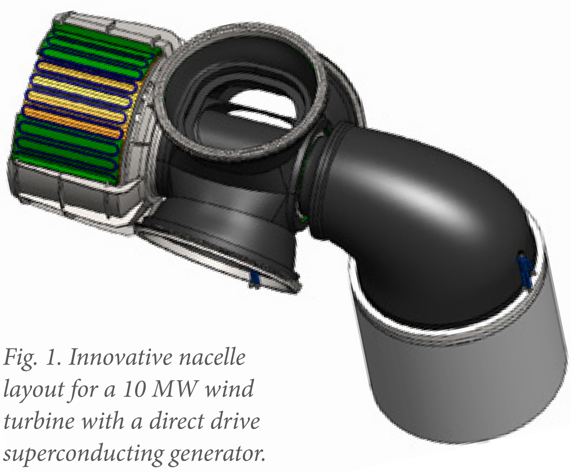


Fig. 1. Innovative nacelle layout for a 10 MW wind turbine with a direct drive superconducting generator.

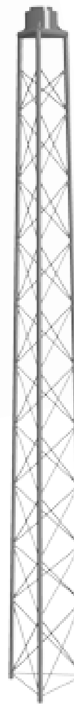


Fig. 2. Three legged full-truss jacket support structure for a 10 MW offshore wind turbine

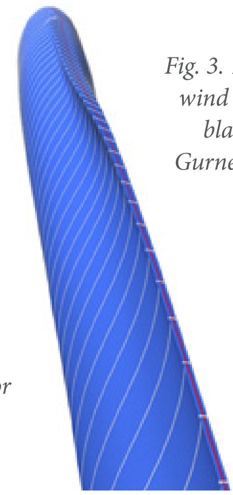


Fig. 3. 10 MW wind turbine blade with Gurney flaps.

The overall objectives of the INNWIND.EU project are the high performance innovative design of a beyond-state-of-the-art 10-20MW offshore wind turbine and hardware demonstrators of some of the critical components. These ambitious primary objectives lead to a set of secondary objectives, which are the specific innovations, new concepts, new technologies and proof of concepts at the sub system and turbine level.

The secondary project objectives will deliver inputs to an iterated beyond-the-state-of-the-art wind turbine design, which fulfils the goal of bringing the 10-20 MW offshore wind turbine to an acceptable performance level. The progress beyond-the-state-of-the-art is envisaged as an integrated wind turbine concept with

1) a light weight rotor having a combination of adaptive characteristics from passive built-in geometrical and structural couplings between deformations and active distributed smart sensing and control, and
2) an innovative, low-weight direct drive generator and
3) a standard mass-produced integrated tower and substructure that simplifies and unifies turbine structural dynamic characteristics at different water depths.

Three hardware demonstrators of the innovations will be made with the aim to significantly reduce the rotor nacelle assembly cost and facilitate faster development of the technologies towards marketability and commercial use.

The project is divided into four scientific core work packages, each delivering different aspects of the overall program and supported by two non-core packages on dissemination/exploitation and project management. There is very close interaction and collaborations between the different work packages. There are three component-specific work packages (WP2-WP4) whose objectives are to deliver conceptual innovations and demonstrations of the core components of the 20MW wind turbine. Supporting these three component-specific work packages is an integrating work package (WP1) which is responsible for evaluating the innovations developed at the component level, integrating advanced controls for optimal performance, further innovations at the system level and integrating the conceptual designs of the innovative components into the turbine.

The key innovations being developed by the project include Superconducting generators, Magnetic Direct Drive Generators, 10 MW- 20 MW capacity fixed and floating sub structures and advanced light weight blades.

By Anand Natarajan and Peter Hjuler Jensen

www.innwind.eu

EUROPEAN ENERGY RESEARCH ALLIANCE – DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTERS

European Energy Research Alliance – Design tools for offshore wind farm clusters is FP7 project with vision to deliver a robust, efficient, easy to use and flexible tool created to facilitate the optimised design of individual and clusters of offshore wind farms.

The European Energy Research Alliance (EERA) partners in the Design tools for offshore wind farm clusters (DTOC) project contribute expertise consolidated in software for offshore wind farm cluster planning. Software is developed on national funding during years by partners and is here for the first time combined on a commen platform. Thus, the main component of the EERA DTOC project is to provide tool useful for wind farm developers and strategic planners. Our industrial partners are defining the user stories, i.e. providing guideline for the practical use of DTOC. The 22 partners include EERA science partners DTU Wind Energy with Peter Hauge Madsen as lead, CENER, CIEMAT, CRES, ForWind, Fraunhofer IWES, SINTEF, Uni Porto, and Uni Strathclyde and from industry Carbon Trust, E.On, IBERDROLA, RES, and Statoil. It is a very wide cross-disciplinary collaboration and fruitful for making a difference. The launching of DTOC will take place at the EWEA Offshore Conference 10-12 March 2015 at the Bella Center in Copenhagen. New scientific learnings highlights are 1) wind farm wakes from satellite and State-of-the-art wake modelling compare well, and 2) ship-based lidar profiles behind wind farm compared to wake modelling.

By Charlotte Hasager and Gregor Giebel

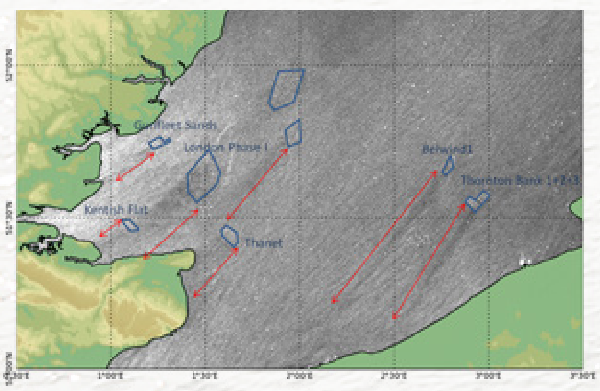


Fig. 1. Offshore wind farm wakes in the North Sea observed by Radarsat-2. The SAR image is processed by CLS. Copyright RADARSAT-2 Data and Products © MacDonald, Dettewiler and Associates Ltd.

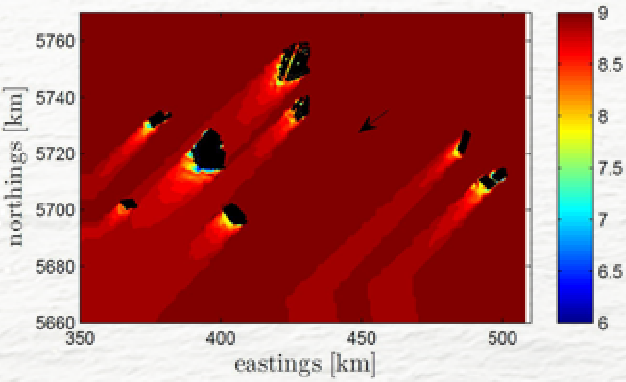


Fig. 2. Wind farm wake modelled from WAsP. Courtesy: Alfredo Peña.

EERA DTOC

THE EUROPEAN ENERGY RESEARCH ALLIANCE
DESIGN TOOLS FOR OFFSHORE WIND FARM CLUSTER

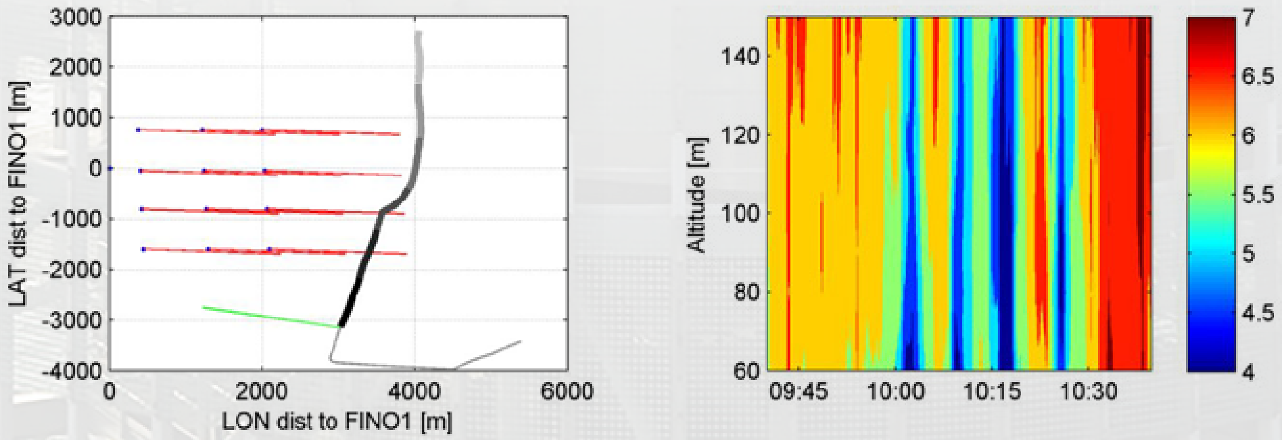


Fig. 3. The left panel shows alpha ventus wind farm with wake in red. Wind direction is from the west. In grey line track of ship with wind profiling lidar moving from north to south. Right panel shows wind speed observed from ship at 1 min resolution. Courtesy: Fraunhofer IWES and ForWind.

IRPWIND – TOWARDS STRENGTHENING INNOVATION AND COLLABORATION IN EUROPE

DTU Wind Energy coordinates 6 EU projects and one of the new projects, coordinated by the Department, is the Integrated Research Programme on Wind Energy (IRPWIND).

The aim of IRPWIND is to strengthen collaboration in European wind energy research. IRPWIND is a 4-year project and started 1 March 2014. IRPWIND is closely linked to the EERA Joint Programme on Wind Energy with the mission to provide strategic leadership for the technical medium to long-term research and to support the requested ambitions for wind energy development and deployment.

Traditionally, European research organisations have competed against each other with temporary collaboration in EU-projects or bilateral projects. IRPWIND adds a more strategic and long-term approach that enables researchers to pool relevant parts of their pre-competitive research efforts in order to foster better integration of European research activities in specific technology domains with the aim to maintain and increase European competitiveness.

IRPWIND gives DTU Wind Energy the possibility to continue the strategic and proactive approach towards European collaboration and funding of research in Horizon 2020. The total budget for IRPWIND is almost 10 M EUR. 6 M EUR for 3 technical core projects in the area of offshore wind farms, structural reliability and European-scale wind farm cluster control and approximately 4 M EUR for "Coordination and Support Actions", which among others co-fund the EERA JP Wind Secretariat, development of strategies and reports and an IRPWIND mobility scheme. The mobility scheme within IRPWIND is created to facilitate the cooperation between IRPWIND research organizations and the broad scientific community to fill gaps in the European wind energy sector.

By Christian Damgaard

OFFSHORE WIND ENERGY PLANNING IN TYPHOON PRONE SEAS

In the Sino-Danish Renewable Development Programme, DTU Wind Energy contributes through research in order to address the challenges in offshore wind farm planning in seas where tropical cyclones occur. It is through international collaboration with the China Meteorological Administration in Beijing and the Hainan Climate Center in Haikou, Hainan in the South China Sea.

China has installed around 91 GW wind power capacity on land. This is far more than any other country. In China the ambition is to also install a significant share of wind turbines offshore, but this process is slow due to several challenges. One is lack of necessary information on the physical meteorological conditions. The project objective was to develop a practical, reliable and robust method for offshore wind resource assessment that can be applied for other potential offshore wind farm sites in China and elsewhere.

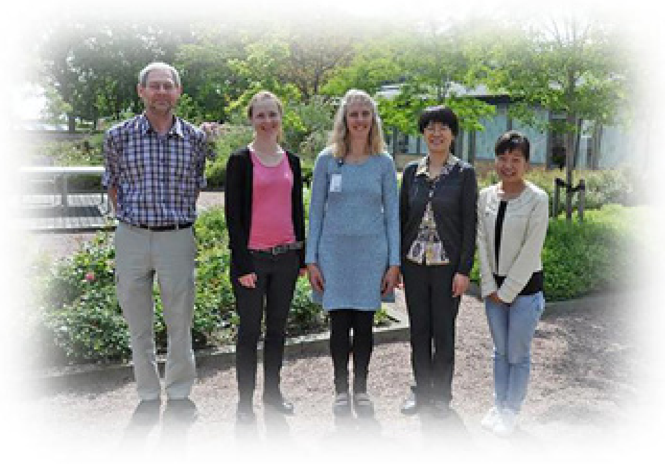


Fig. 1. Project team meeting at DTU Wind Energy.

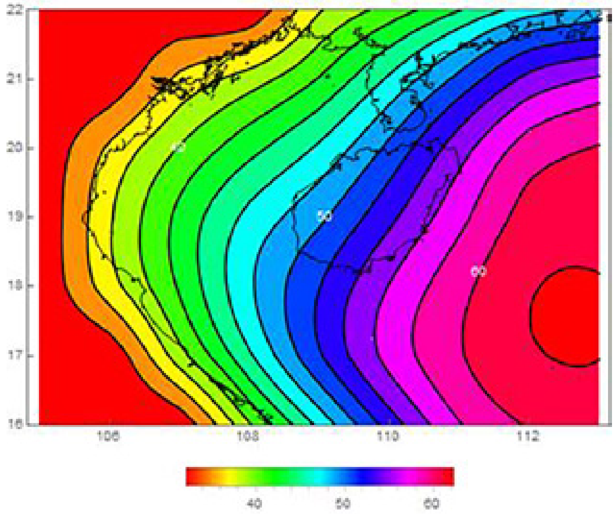


Fig. 3. Extreme wind atlas at 100 m for part of the South China Sea.

During the 2-year project "Study on Offshore Wind Resource Assessment Based on Satellite Data and Modeling" DTU Wind Energy has contributed knowledge on satellite remote sensing for offshore wind resources and assessment of extreme wind condition. The 50-year extreme wind speed, also called design winds relevant for wind turbines, is estimated for parts of the South China Sea where several wind farms are in planning.

By Charlotte Hasager and Merete Badger

Fig. 2. Photo of coastal meteorological mast at South China Sea.

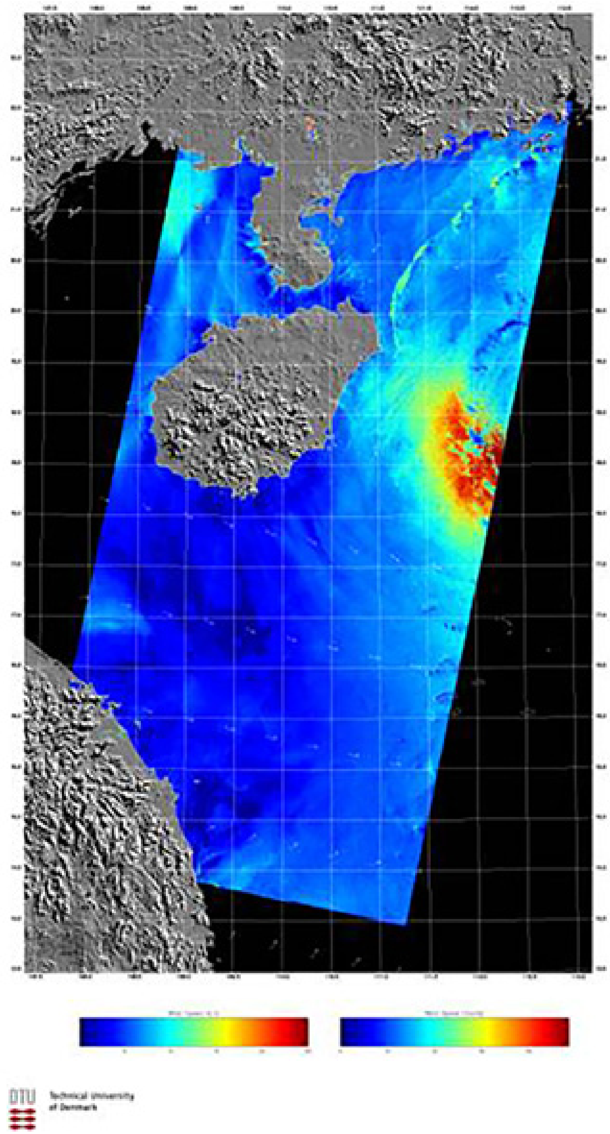


Fig. 4. Satellite images showing Typhoon Chanthu.

EDUCATION

DTU Wind Energy performs education and training in most wind energy related disciplines, comprising as different topics as aerodynamics, atmospheric physics and meteorology, aero-elasticity, aero-acoustics, composite materials, grid integration, offshore wind energy, dynamics of machinery, measurement techniques, and planning.

DTU Wind energy offers at the moment 12 candidate courses and four PhD courses every year.

As the one of the only Departments in the world, DTU Wind Energy offers a complete 2 years master's programme in wind energy. DTU Wind Energy also contributes to three master's programme:

1) the M.Sc. in Sustainable Energy program, which has different specializations including one in wind energy,
2) the Nordic master's programme in innovative and sustainable energy (ISEE), where the students study at two or more technical universities in the five Nordic countries, and
3) the Erasmus Mundus European Wind Energy Master (EWEM), which is a two year double degree programme. The partners in the programme are Delft University of Technology, NTNU, Carl von Ossietzky Universität Oldenburg, with DTU being responsible for the first semester and the wind physics and the rotor design tracks.

DTU Wind Energy is also responsible for the DTU/KAIST double-degree programme in Offshore Wind Energy.

DTU Wind Energy develops PhD courses with research topics relevant for wind energy. This takes place in collaboration with the research schools Danish Centre for Applied Mathematics and Mechanics (DCAMM) and Danish Academy in Wind Energy (DAWE), as well as in collaboration with the European Academy in Wind Energy (EAWE).

DTU Wind Energy contributes to life-long learning/continued education by offering a number of training courses for industry staff, from Denmark and internationally. Many training courses are tied to the software products, developed as part of our innovation activities, or are offered as advanced courses, based on or combined with our PhD courses.

One of the goals of DTU Wind Energy is to develop E-learning courses, specifically offered as continued education for people employed in the wind industry. In the planning period we expect 5 to 6 new courses to be introduced as E-learning.

HIGHLIGHTS EDUCATION

PhD Student, Master of Wind Energy, Master of aerospace Emmanuel Branlard received an 'Elite-Research' travel scholarship from the Danish Agency for Science and Innovation. "The prize was used to visit and work with some of the world's leading experts in vortex methods. This included in particular, the group of the National Technical University of Athens, Greece, and the University in Louvain-la-Neuve, Belgium.

PhD student Farzad Foroughi Abari attended the 17th International Symposium for the Advancement of Boundry-Layer Remote Sensing held in January in Auckland, New Zealand.
There he won the best student presentation award at IRSARS conference.
On the photo you see Farzad to the left.

EWEA Conference 2014
At the EWEA Conference's poster award session Tilman Koblitz received an award for having made the best poster in the category Resource Assesement.
There were three tracks in total: Hardware Technology, Resource Assessment and Science & Research, and for each track two posters were awarded (one from academia, one from industry).

The PhD competition at The Danish Wind Energy Annual meeting in Herning from 26-27 March 2014 was won by Iva Hrgovan from DTU Wind Energy.
The event took place in Herning with 400+ participants from industry and research institutions.

"We had 12 PhD students lined up to give 5-minute highlight presentations and present a poster at a dedicated poster session. There were many great contributions which made the PhD participation a true asset of the event", says Henrik Bredmose, co-organizer and associate professor at DTU Wind Energy.

Iva Hrogovans work concerns the design of low noise blades for large wind turbines.

DTU Vindenergi participated in Forskningens Døgn
Niels-Erik Clausen participated in the event called Order a Scientist at "Forskningens Døgn" 24 April.
It is an annual event facilitated by the Ministry of Education and Research intended to arouse public interest in and enhance public understanding of ongoing or past research and science activities at Danish Universities and companies.
Niels-Erik participated in 2014 by giving two lectures on wind energy; the first lecture took place at Roskilde Katedralskole for a 3g (final year) class studying climate change and the energy system and the second lecture took place in the evening in Ørslev between Ringsted and Haslev, where he was invited by the local association of citizens (Borgerlaug). The small community here are likely to become neighbour to a wind farm in the near future and wanted to know more about wind energy and the effects of living near modern wind turbines.

Industrial PhD receives an award
The composite Section's Research and Education award promotes awareness and interest in composite materials among students while strengthening cooperation with the country's educational institutions.
"There were many very qualified candidates for this year's Research and Educational award, but there was broad consensus that Jens Zangenberg's industrial PhD project was in a class by itself.
It is an excellent example of fruitful collaboration between the composite company by LM Wind Power and the academic world, DTU Wind Energy.

The team behind this year's winner of 'Grøn Dyst' at DTU made a study of the effect of a ship propeller if used as a mill to operate the electric on the ship while the ship is under sail. They studied a marine propeller model from all angles pitch / blade angles and found out that the effect had an efficiency of up to 20%.

Students from left are:
Nicklas, Andrew, Emil, Merle, Jacob, Thor, Søren and Sebastian with Robert Mikkelsen from DTU Wind and Poul Andersen from DTU Mechanical Engineering. The project is conducted in cooperation with Hundested Propeller, DTU Mechanical Engineering, DTU Wind and FORCE Technology.

Young PhD candidate from DTU Wind Energy honored at this year's graduation party
Rogier Floors, who has written the thesis: 'Measuring and modeling of the Wind on the scale of all wind turbines', was at this year's graduation party for PhDs' awarded the 'Young Researcher Award' along with five other PhDs' from DTU.
Awards are annually awarded to young researchers who have made an extraordinary effort and who have great potential to develop within their reserach field.
Rogier Floors is seen in the middle of the picture.

DTU WIND ENERGY NOW INVOLVED IN RUNNING COURSES AT DTU DIPLOMA

As a consequence of the fusion of "Copenhagen University College of Engineering" with DTU in 2013, DTU Wind Energy has been involved in teaching DTU Diploma students. This was initiated in the fall of 2014 with two shared courses with DTU Mechanics. The aim for both courses was teaching the Finite Element Method for students on the Building and Machine study direction. The DTU Wind Energy department is extensively using commercial finite element codes and build on these competences, a total of 115 diploma engineering students were taught mastering a commercial finite element code solving different structural problems. The activity is planned to be extended to other fields in 2015.

By Lars P. Mikkelsen

Fig. 1. The course was evaluated through two small projects and a final multiple choice exam, here shown during the marking of Lars P. Mikkelsen and Kristine M. Jespersen.

NEW BACHELOR COURSE INTRODUCING WIND ENERGY

Why does a modern wind turbine have three blades and how competitive is wind energy to coal-based energy? What is a permanent magnet generator and why are the turbines getting increasingly large? Questions like these are the starting point in a new bachelor course that ran for the first time in the spring of 2014.

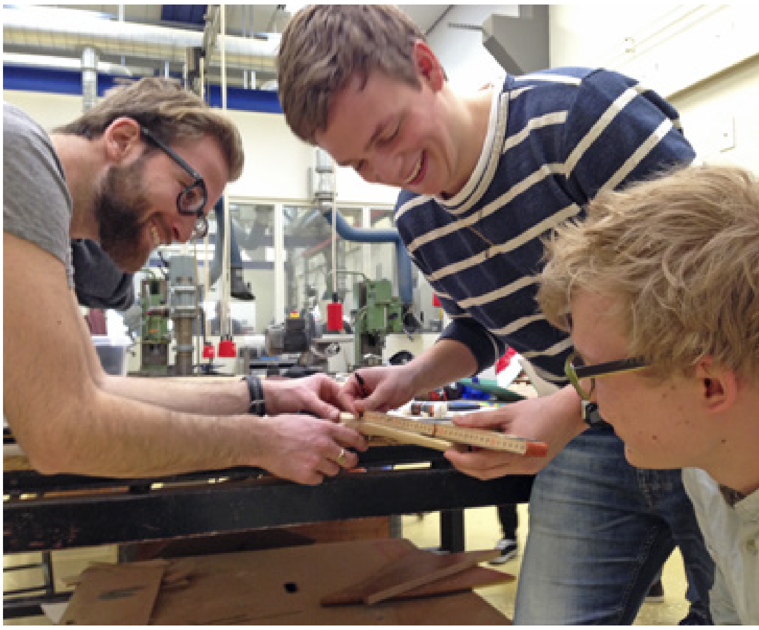


Fig. 1. Concentrated rotor fabrication in the wood workshop.

Wind energy is a broad topic that draws on many engineering disciplines. A good overview of wind energy technology and the basic methods are a good foundation for further studies at the master courses. This was the outset for the planning of course, which was also intended to expose more students to wind energy before they enter into the master level.

"We decided to put in a good deal of hands on, to make the theory and topic real for the students", explains Henrik Bredmose, associate professor and course responsible. The two other core points in the planning were a down to earth perspective and application of simple (almost) hand-based calculation models.

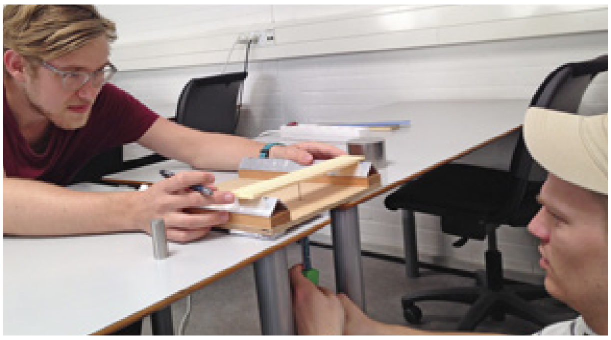


Fig. 2. Stiffness measurement of core layer.

Carve a rotor and produce a sandwich beam

The hands on experience was achieved through three experimental exercises. In one of them, the students carve a 2-bladed rotor in wood and compete on its performance in the lab. A seemingly simple task, but with lots of room for aerodynamic discussions and insight. In another exercise, the students fabricated a sandwich beam in the class room and tested the stiffness increase by the outer skin layers. "Here our approach of double layer tape to glue the layers together turned out to introduce yielding between the core and the skins. Again we had good opportunity to discuss the topic with the students. Next year, though, we have a better plan", smiles Henrik Bredmose.

The majority of the course exercises where in Matlab. The exam was therefore also in Matlab and tested the student skills in application of the simple models presented in the course. It is exactly this combination of a good overview, ability of simple calculation methods and enthusiasm for the topic we want to convey to the students.

Material from all sections

The course has been anchored to the full department through a contact person in each section that helped selecting the content of the specific course modules. Also through the three exercises, the students met a range of researchers from the department. This gives a feel for the variety of topics and specializations wind energy covers. While the next round of the course will commence in February 2015, we thus hope to see the 2014 students back in later master level courses.

PHD SUMMER SCHOOL: REMOTE SENSING FOR WIND ENERGY

The participants at this year's PhD Summer School: Remote Sensing for Wind Energy were 18 PhD students enrolled at universities in eight countries including Belgium, Denmark, Germany, the Netherlands, Russia, United Kingdom and USA. Recruitment of talented and motivated young PhD students have global reach so the participants origin were also from e.g. China, Greece, Iceland. There were four industry participants from Brazil, Denmark and France.

The main topic was lidar. This technology has proven extremely useful for a wide variety of applications in wind energy. The most recent successful technology is scanning lidars. However, the course has broader aims and includes several other techniques such as sodar, radar and other instruments. The themes covered are development, instrument configuration, signal processing, data analysis and applications of various remote sensing instruments: SODAR, LIDAR, RASS, ceilometers and SAR among others, both ground- and satellite-based instruments. The PhD course has been held several years and so far more than 200 PhD students and industry participants have benefitted from this. The technological development is very fast in this discipline, thus naturally the course constantly has been updated to allow cutting-edge lecturing.

PHD PROJECTS – 3RD YEAR STUDENTS

Name/nationality
Imad Abdallah / Canadian

Start and end of PhD project
Start: 2012
End: 2015

Project title
Aspects of uncertainty quantification with applications to extreme loads on wind turbines

Section
Wind Turbines Structures

Supervisor/co-supervisor
Main supervisor: Anand Natarajan
Co-supervisors: John Dalsagaard Sørensen (AAU), Lars Risager (MiTa-Teknik

Funding
50% MiTa-Teknik, 50% Innovation Fund Denmark

Project Description
- Effect of uncertainty in aerofoil aerodynamics on extreme loads.
- Effect of advanced load alleviation control features on the wind turbine structural reliability and partial load factors.
- Fusion of seeveral aero-servo-elastic model results, and assessment of the corresponding model uncertainty

Perspective
The main contribution of the project is the quantification of sources of uncertainty affecting the extreme design loads on a wind turbine, structural reliability and safety factors.

Contact
Imad.abdallah.81@gmail.com, ima@mita-teknik.com

Name/nationality
Tuhfe Gocmen Bozkurt / Turkish

Start and end of PhD project
Start: 2012
End: 2015

Project title
PossPOW: Possible Power of Offshore Wind power plants

Section
Wind Energy Systems

Supervisor/co-supervisor
Main supervisor: Gregor Giebel
Co-supervisors: Poul E. Sørensen, Niels Kjølstad Poulsen (DTU Compute)

Funding
PSO

Project Description
In a down-regulated wind farm, the sum of the individual possible and active power signals is not equal since the downstream turbines see more wind that would be there without the regulation. Currently the TSOs have no real way to determine exactly the possible power of a down-regulated wind farm.

Perspective
We aim at a verified and internationally accepted way to determine the possible power of a down-regulated offshore wind farm. Along the way, we also aim at improving the use of wake models for real-time cases.

Contact
tuhf@dtu.dk, tuhfegocmen@mail.com

Name/nationality
Emmanuel Branlard, French

Start and end of PhD project
Start: April 2012
End: April 2015

Project title
Analysis of Wind Turbine Aerodynamics and Aeroelasticity Using Vortex Based Methods

Section
Aeroelastic Design

Supervisor/co-supervisor
Main supervisor: Mac Gaunaa

Funding
DSF-Flowcenter

Project Description
This PhD project uses both the simplified analytical approach and the advanced numerical approach to study wind turbine aerodynamics and aeroelasticity. The project focus on unsteady aerodynamic conditions such as: yaw, shear and turbulence.

Perspective
Simplified vortex analyses allows for the development of engineering models to improve the performance of the traditional design codes. Vortex code results give better insight into wind-turbine aerodynamics at a reasonable computational time.

Contact
ebra@dtu.dk

Name/nationality
Juan Felipe Gallego-Calderon, Colombian

Start and end of PhD project
Start: 2012
End: 2015

Project title
Electromechanical Drivetrain Simulation

Section
Wind Turbine Structures

Supervisor/co-supervisor
Main supervisor: Anand Natarajan
Co-supervisors: John M. Hansen (DTU Mek), Nicolaos Cutululis (VES), Kim Branner (VIM)

Funding
Danish Research Council for Strategic Research, grant no. 10-093966.

Project Description
The purpose of this PhD project is to study the electromechanical interaction between the rotor and the generator, and the resulting drivetrain loads. The responses of different components of the drivetrain will be investigated, along with experimental testing to develop new conceptual designs of the drivetrain with improved reliability.

Perspective
A simulation tool that includes the wind turbine structure, a detail gearbox model, a dynamic generator and a simplified power system will be developed. The models will contribute in the system simulation of large wind turbines to study the impact from the mechanical (wind turbine structure) and electrical (generator and grid dynamics) dynamics in the loading of the internal components of the drive-train, in where reliability is paramount for the wind turbine operation.

Contact
jugc@dtu.dk

Name/nationality
Philipp U. Haselbach, German

Start and end of PhD project
Start: 2012
End: 2015

Project title
Ultimate strength of wind turbine blade structures under multi axial loading

Section
Wind Turbines structures

Supervisor/co-supervisor
Main supervisor: Kim Branner
Co-supervisors: Robert D. Bitsche, Christian Berggreen (DTU MEK)

Funding
Danish Centre for Composite Structures and Material for Wind Turbines (DCCSM)

Project Description
The influence of multi axial loads and the blade geometry on the ultimate strength of typical composite structures in wind turbine blades are investigated. Improved methods to predict more reliable failures under complex loading are developed.

Perspective
The study will provide a better understanding of how multi axial loads and blade geometry affect the ultimate strength of composite structures in wind turbine blades. Failure predictions methods and design guidelines will be presented to assess damages and to improve the structural design.

Contact
phih@dtu.dk

Name/nationality
Iva Hrgovan, Croatian

Start and end of PhD project
Start: 2012
End: 2015

Project title
Aerodynamic and structural design of wind turbine blades

Section
Fluid Mechanics

Supervisor/co-supervisor
Main supervisor: Wen Z. Shen
Co-supervisors: Jens N. Sørensen, Christian Berggreen

Funding
EUDP NextRotor10-093966.

Project Description
The growing issue of acceptance of large onshore turbines is due to the emitted noise. The project aims to demonstrate that a coupled aerodynamic, aeroacoustic and structural design optimization can lead to high performance and low noise rotors. New thick airfoils were also designed in the project.

Perspective
The developed optimization process is modular and can be used for designing blades of other sizes and for different objectives; the system can also be upgraded to accommodate more advanced aeroelastic models. New airfoil series can be used in other blades.

Contact
ivah@dtu.dk

Name/nationality
Susana Rojas Labanda / Spanish

Start and end of PhD project
Start: 2012
End: 2015

Project title
Mathematical programming methods for large-scale structural topology optimization

Section
Wind Turbines Structures

Supervisor/co-supervisor
Main supervisor: Mathias Stolpe
Co-supervisors: Ole Sigmund

Funding
Villum Foundation through the project Topology Optimization- the Next Generation (NextTop).

Project Description
This PhD project has two main objectives. First, to perform extensive numerical tests and compare the commonly used first-order special purpose optimization algorithms in the field of structural topology optimization, with existing state-of-the-art general purpose optimization methods. The second part of the project consists of developing, analyzing, implementing and benchmarking efficient second-order optimization methods which can utilize the particular mathematical structure of large-scale-structural topology optimization problems.

Perspective
The benchmark of the different numerical methods for topology optimization problems is, since long, requested by the community. We expect that second-order nonlinear general purpose solvers will outperform respect to structural topology optimization methods. Moreover, special purpose second-order solvers are expected to produce more accurate designs reducing significantly the convergence rate than any other solver used in the community.

Contact
srla@dtu.dk

Name/nationality
Nadia Najafi, Iranian

Start and end of PhD project
Start: 2012
End: 2015

Project title
Experimental Stereo Vision Studies of Flow and Structural Effects on Wind Turbines

Section
Wind Energy Systems

Supervisor/co-supervisor
Main supervisor: Uwe S. Paulsen
Co-supervisors: Jakob Mann (DTU), Mikael Sjöholm (DTU)

Funding
Partly by DeepWind and partly by its own

Project Description
In operational modal analysis (OMA) displacement measurements provide the proper data sets to be analyzed for the dynamic behavior of the structures. I am measuring the displacement s on the different parts of a VAWT with stereovision techniques in my PhD. This system enables measuring the displacements just by two cameras and an image acquisition system. Displacements that are extracted by the image processing are less noisy and more reliable rather than other measurement tools like accelerometers which are suffered from electronic noise and affected by operation condition. In the other part of my PhD., I am using the Background Oriented Schlieren (BOS) method to study the tip vortices behind a horizontal axis wind turbine. This method uses the refractive index change due to the density gradient in the vortex core to quantify the tip vortices.

Perspective
In the first part of the project a measurement system will be developed to measure the displacements on the big structures based on the images and analyzing the measurement time series to get the modal properties. In the second part a set of measurement try to quantify the tip vortex behind a HAWT and propose the experiment designs.

Contact
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Name/nationality
Henrik Alsing Friberg, Danish

Start and end of PhD project
Start: 2012
End: 2016

Project title
Mixed-Integer Optimization over Second-Order Cones and Industrial Applications.

Section
Wind Turbine Structures

Supervisor/co-supervisor
Main supervisor: Mathias Stolpe
Co-supervisors: Kent Andersen (Aarhus University), Erling D. Andersen (MOSEK ApS)

Funding
MOSEK ApS and the Danish Ministry of Higher Education and Science.

Project Description
Mixed-integer conic optimization is thought to be a promising approach to improve the performance of minimizing costs or optimizing properties of structures with discrete design choices subject to nonlinear convex constraints. This project aims to mature these techniques for practical applications.

Expected outcome/Perspective
The project takes a bottom-up approach in which a file format is developed to replace MATLAB files, and a benchmark library is established as reference for validation of theory and solvers. Addressing recent concerns, deeper understanding of strong duality and pros/cons of linearization is expected.

Contact
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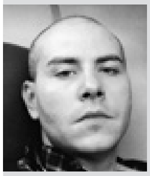
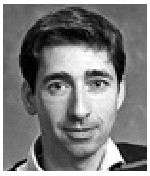
PHDS IN 2014

	Name/nationality	Contact	Project title	Year start - year finished	Section	Supervisor	Funding:
	Hamid Sarlak Chivaee	hsar@dtu.dk	Large Eddy Simulation of Turbulent Flows in Wind Energy.	2011-2014	Fluid Mechanics	Professor Jens N. Sørensen /Senior Researcher Robert F. Mikkelsen	This research was carried out as part of the Statkraft Ocean Energy Research Program (SOERP), sponsored by Statkraft and the DTU COMWIND.
	Nikola Vasiljević	niva@dtu.dk	Flow measurements in complex terrain using a 3D LIDAR Windscanner	2010-2013	Test and measurements	Senior Researcher Michael Courtney/ Professor Jakob Mann	The Ph.D. project was funded by the European Commission through the Marie Curie FP7-ITN- WAUDIT Project, under the grant number # 238576.
	Neil Davis	neda@dtu.dk	Icing Impacts on Wind Energy Production	2011-2014	Meteorology	Senior Scientist Andrea Hahmann / Associate Professor Niels-Erik Clausen / Mark Žagar	This research was carried out as part of the Improved Forecast of Wind, Waves and Icing (Icewind) Top-level Research Initiative (TFI), sponsored by Vestas Wind Systems A/S.
	Alemseged Gebrehiwot Weldeyesus	alwel@dtu.dk	Free Material Optimization of Wind Turbine Blades	2010-2014	VIM	Senior Researcher Mathias Stolpe/ Professor Erik Lund	Danish Centre for Composites Structures and Materials (DCCSM).
	Patrick J.H. Volker/ Dutch	pvol@dtu.dk	Wake effects of large offshore wind farms - A study of the mesoscale atmosphere.	2010-2014	Meteorology	Andrea N. Hahmann /Senior Researcher, Jake Badger/Senior Researcher and Søren Ott/Senior Researcher	Marie Curie ESR-FP7
	Christina Koukoura		Validated loads prediction for offshore wind turbines for enchanced component reliability	2011-2014	Wind Turbine Structures	Anand Natarajan	Danish EUDP project titled: Offshore wind turbine reliability through complete loads measurements
	Konstantinos Marmaras	komar@dtu.dk	Optimal Design of Composites Structures under Manufacturing Constraints	2011-2014	Composites and Material Mechanics	Mathias Stolpe	The Danish Council for Independent Research - Technology and Production Sciences (FTP) under the grant "Optimal Design of Composite Structures under Manufacturing Constraints"
	Adriana Hudecz	ahud@dtu.dk	Icing Problems of Wind Turbines in Cold Climate	2011-2014	Fluid Mechanics	Martin O. l. Hansen	DTU Wind Energy
	Dmitry Kolmogorov	dkol@dtu.dk	Finite Volume Methods for Imcompressible Navier-Stokes Equations on Collocated Grids with Nonconformal Interfaces	2011-2014	Fluid Mechanics	Wen Zhong Shen	DTU Wind Energy/DSF

DEVELOPMENT OF COMPONENT AND SUB SUPPLIERS IN THE DANISH WIND TURBINE INDUSTRY

At DTU Wind Energy, we focus on innovation and value creation for the entire wind turbine industry and for many years, the main industrial collaboration has been with the major turbine manufacturers. A significant amount of the activities in the industry is, however, carried out with component and sub suppliers – and in order to continue the development within this part of the sector a new project initiative aims at strengthening the relationship between the research community at DTU and the industry.

The Danish Industry Foundation has sponsored the project Development of component and sub suppliers in the Danish wind turbine industry. The project group consists of several departments from DTU and the Danish Wind Industry Association.

Through interviews with approximately 20 case companies, the technical challenges with sub suppliers are mapped and the potential for further value creation based on the research competences within DTU is investigated.

The aim is to utilize the potential of the wind turbine system competences, including the interaction between components and the various test facilities at DTU for further development of products at the individual sub suppliers and to ensure that this product development become less dependent on the main turbine manufactures.

The future collaboration between the sub supplier section of the wind turbine industry and DTU will be supported through a workshop during spring 2015 at DTU.

By Kenneth Thomsen

NEW INNOVATION MANAGER TO DTU WIND ENERGY

Kenneth Thomsen has been appointed Innovation manager at DTU Wind Energy. Organizationally he will be part of LAM Secretariat. The Innovation manager will in future be included in the institution's management group. Kenneth started with immediate effect. From an organizational point of view the purpose is strengthen the collaboration with companies and innovation efforts in general. In this regard Head of Department Peter Hauge said: *"For the department it is crucial to ensure that research is applied and utilized in society, and it is my expectation that Kenneth can contribute to the continuous strengthening of the innovation efforts"*.

FULL HOUSE – ALL TEST STANDS AT ØSTERILD TEST CENTRE LEASED OUT

In 2014 DTU leased out the last two vacant test stands at Østerild Test Centre. The vacant test stands were auctioned, and more bids were received than could be satisfied.

In 2012 The National Test Centre for Large Wind Turbines was established with 7 test stands and allows for erection of wind turbines of up to 210 and 250 meters, respectively.

Test stand number 1 has been leased to EDF Energies Nouvelles from France. EDF will use the test stand to test and refine the wind turbine they expect to use in the years ahead for planned offshore wind farms in France. EDF has chosen to use Alstom's 6 MW wind turbine in its French offshore wind farms, and will conduct the tests jointly with the wind turbine manufacturer.

Test stand number 4 has been leased to Vestas Wind Systems. Vestas already has two test stands at Østerild Test Centre, but needs additional test capacity for testing and further developing their wind turbines. The test stands will be taken over in early 2015.

DTU is pleased to be able to offer Vestas yet another test site and continue the good partnership. We also look very much forward to partnering with EDF Renewables and Alstom.

By Lotte Krull

BECAS V.3.0 IS NOW AVAILABLE:

BECAS is DTU Wind Energy's cross section analysis software. After two years of hard work we are proud to announce the new BECAS v3.0 has been released! This is the latest stable version of BECAS's source code including a large number of new functionalities and significant improvements in efficiency and usability, namely:

- **A new strength analysis module** featuring failure criteria relevant for composite structures is now fully implemented and validated;
- **A new fracture mechanics module** based on the Virtual Crack Closure Technique has been implemented and validated;
- **New template files** are included to support the users developing their own frameworks.
- **Significant overall improvements** to the code have led to increased efficiency and usability.
- **The pre-processing tools ShellExpander and Airfoil2Becas have been updated** to include the composite failure criteria and handle arbitrary number of regions for composite layup definition, respectively.
- **A new plugin to OpenMDAO**, a framework for multidisciplinary analysis and optimization, is now available.

BECAS is available free of charge for academic use and for an annual fee for commercial use. More information is available at the BECAS website: http://www.becas.dtu.dk.

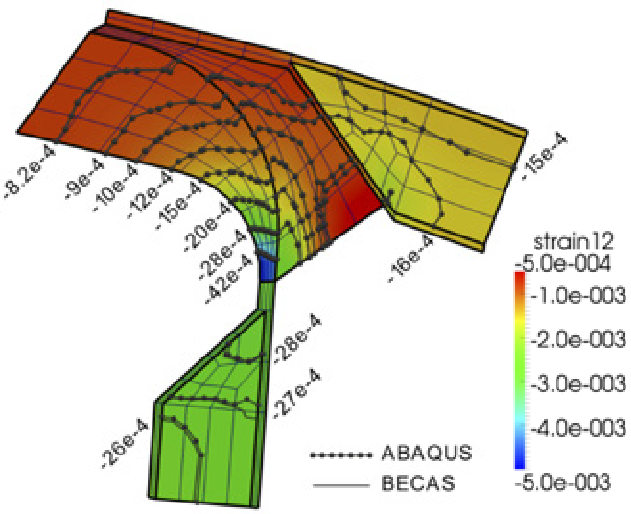


Fig. 1. Shear strains at the intersection between shear web and cap of a wind turbine blade. Results obtained using the new BECAS strength analysis module show very good agreement with 3D finite element model.

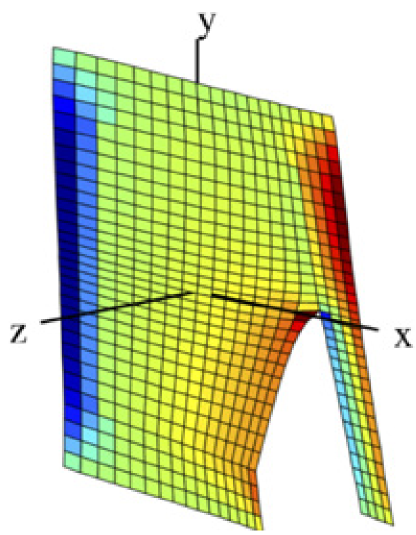
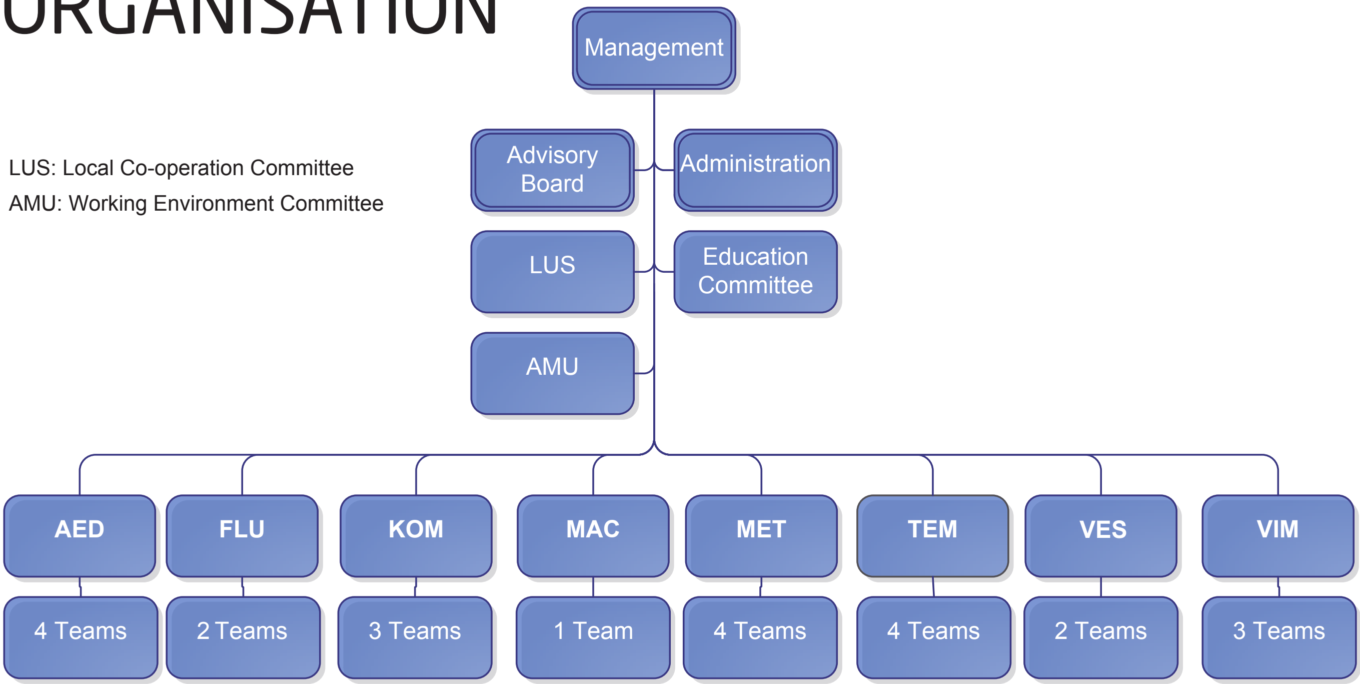


Fig. 2. New BECAS fracture analysis module based on VCCT allows for accurate evaluation of the crack tip strain energy release rates GI, GII, and GIII.

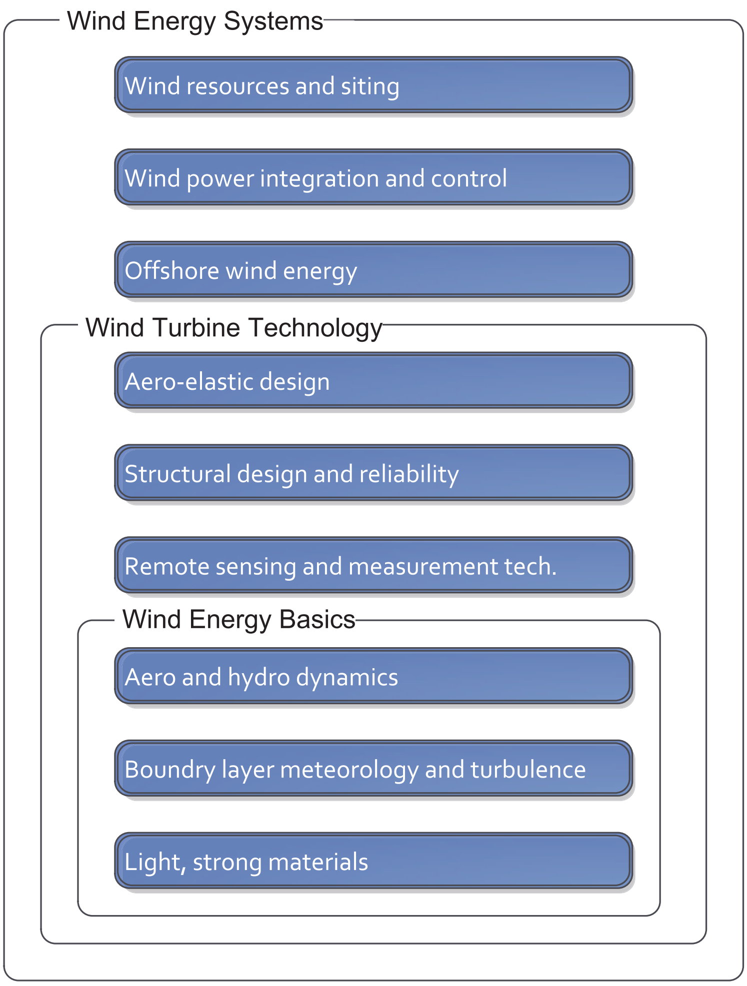
ORGANISATION



The management of the department consists of the Head of Department and the Deputy Head of Department. The management structure of the department is organized with a single management team with the Head of Department as chairman and the Deputy Head of Department and the 8 head of sections as members. The organization of DTU Wind Energy is shown in the organizational chart above.

THE 9 RESEARCH PROGRAMMES

The technical/scientific competences within the department are embedded in the eight sections. The research is organized in 9 research programmes within three main research themes: Wind energy systems, where the turbine enters as a component, wind turbine technology and wind energy basics. Each strategic research programme typically has contributions from other sections from the department and cooperation with other DTU departments.



Advisory Board: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Head of Department:


Peter Hauge Madsen

Deputy Head of Department:


Peter Hjuler Jensen

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Aeroelastic Design (AED), Flemming Rasmussen, Head of Section


Composites and Materials Mechanics (KOM), Professor Bent F. Sørensen, Head of Section


Fluid Mechanics (FLU), Professor Jens Nørkær Sørensen, Head of Section


Materials Science and Characterisation (MAC), Professor Dorte Juul Jensen, Head of Section


Meteorology section (MET), Dr. Hans E. Jørgensen, Head of Section


Test and Measurements (TEM), Dr. Poul Hummelshøj, Head of Section


Wind Energy Systems (VES), Jens Carsten Hansen, Head of Section


Wind Turbine Structures (VIM), Dr. Thomas Buhl, Head of Section

Study Programmes:


Study Committee, Dr. Niels-Erik Clausen, chairman


Erasmus Mundus European Wind Energy Master, Professor Jens Nørkær Sørensen


Master Programme in Wind Energy, Ass. Professor Martin L. Hansen

TEAM DESCRIPTIONS

After the first year as a department comprising 250 employees divided into 8 sections and an administration, the management decided to further divide the sections into smaller and unique teams in order to support the scientific and staff development taking place in a department characterized by cross-disciplinary research. The teams have different techincal or scientific areas:

Aeroelastic Design Section is divided into four teams:

Aerodynamics, aeroacustics, airfoil and blade design team:
The team works with aerodynamic and aeroacoustic research for airfoil and blade design and optimization - modeling and experiments.

CFD for wind turbine design team:
The team addresses CFD for aeroelastic design of wind turbines in wind farms including wakes and terrain.

Aeroelastic stability and control team:
The team works with modeling and analysis of aeroelastic stability and multi-variable control of wind turbines including distributed blade censoring and control.

Aero-hydro-elastics and loads team:
The team addresses aero-hydro-servoelastic modeling, analysis and optimization of wind turbine response and loads under real operational conditions for different concepts.

The Fluids Mechanics Section is divided into three teams:

Aerodynamics and Fundamental Fluid Mechanics team:
The research focuses on a broad spectre from applied aeroelasticity to fundamental study of various flows e.g. wakes behind wind turbines including stability and devices for controlling the boundary layer on blades. Further, advanced numerical methods are used for wake flow and large databases are used for wind farm analysis.

Computational Aerodynamics and Aero-acoustics team:
The team works with numerical simulation tools which are developed for analysis, control and design of wind turbines, including codes for generation and emission of noise from wind turbines and wind farms.

The Composites and Materials Mechanics Section is divided into three teams:

Processing and microstructural characterization team:
The team addresses manufacturing of new types of composite materials, test specimens and prototype by vacuum infusion, autoclave consolidation or hot pressing. Preparation of test specimen by cutting, grinding, polishing and adhesive bonding. Process control by process modelling, microscopy, embedded sensors.

Modelling of materials mechanics team:
The team works with numerical and analytical modelling to describe or predict the mechanical properties of materials by phenomenological or micromechanical models. Modelling of stress-strain laws, cohesive laws and fatigue life laws using solid mechanics, damage mechanics and fracture mechanics concepts.

Mechanical characterization and damage detection team:
The team addresses experimental characterization of mechanical properties of fiber composites, measurement of deformation, stiffness, strength, cohesive laws and fatigue lifetime. Development of improved mechanical testing methods and test specimen design, damage detection and non-destructive evaluation.

Materials Science and Characterization Section

The Materials Science and Characterization Section is organized into one large team. The Section focusses on structural characterization of materials – mostly metals- and relating the structural observations to the processing and the properties as well as the performance of the materials. The work encompasses both experimental characterizations and theoretical modelling.

The Meteorology Section is divided into four teams:

The WAsP team
The WAsP Team carries out research, innovation, software development, education and public sector consultancy within the field of wind flow modelling over terrain for wind resource assessment and site assessment for wind turbines and wind farms.

The MesoWind team:
The team adresses the application of mesoscale modelling in the field of wind energy. Emphasis is on developing methods to accurately calculate wind conditions, apply the results in microscale models, and validate.

Boundary-Layer Meteorology team:
The team carries out basic and applied research on the structure and turbulent dynamics of the lower part of the atmosphere. Topics of current particular interest are wind profiles, wind turbine inflow and wake dynamics, flow in complex terrain, air-sea interactions, flows in and over canopies, effects of stratification on turbulence and wind profiles, turbulent exchanges of energy and gases such as carbon dioxide, turbulence statistics in the atmospheric boundary layer, and coupling of local flow with the meso scale.

Offshore wind power meteorology team:
The team addresses research on offshore wind power meteorology including observation, data analysis and modeling of the marine atmospheric boundary layer relevant for assessment of offshore wind resources and wind farm siting, lay-out, operation, optimization and design.

Wind Energy System Section is divided into two teams:

Wind Energy Systems and Development team:
The team addresses wind farm project planning and development, integrating knowledge for development of wind energy technology and sector development as well as application of advanced active materials in wind turbine generators, short-term prediction, wind power in cold climates and in isolated power systems.

Wind Power Integration and Control team:
The team addresses integration and control of wind energy into power systems. Focus are wind power variability, control and ancillary services from wind power plants, grid connection, integration of large scale offshore wind power and integrated analysis of power systems and wind turbine loading.

The Test and Measurement Section is divided into four teams:

Applied Measurement Technology team:
The team focuses on mowing new, wind related measuring technologies out to the industry and is currently engaged in work with spinner anemometers, kinematic measurements with stereo-vision, ground-based lidars, nacelle-mounted lidars and scanning lidars.

WindScanner Research and Innovation team:
The team focuses on WindScanners space and time synchronized scanning wind lidars deployed and operated for measurement of the 3D wind and turbulence structures in the atmospheric boundary layer, and upwind scanning wind lidars installed on the turbine nacelle and in the rotating turbine.

Experimental Research & Development team:
The team provides the technical expertise needed to perform experimental wind energy research. This means to develop and maintain the needed hardware and software to perform large field experiments, long-term meteorological measurements and measurements on and around wind turbines.

Wind Turbine Testing team:
The team focuses on the activities taking place at the two test stations in Høvsøre and Østerild. The team performs accredited power curve and loads measurements at the prototype wind turbines installed at the test stations. Also DANAK accredited-calibration of ground-based lidars is a part of the team activity.

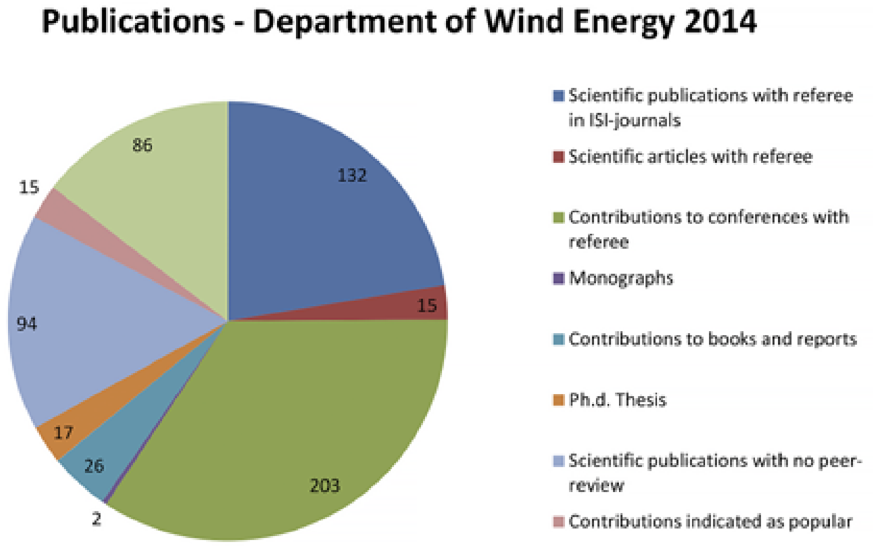
Wind Turbine Structures Section is divided into three teams:

Loads and Component Design team:
The team focuses on reducing model uncertainties in design loads evaluation by improving computational methods, prediction models, wind and wave field characterization, and reducing design loads, and robust techniques, probabilistic design involving lifetime prediction etc.

Structural Design & Testing team:
The team does research in the areas of experimental, numerical and analytical design theory in order to develop more reliable and precise methods for structural design of wind turbine blades and other large composite and metal structures. Also research in understanding failure mechanisms and progressive damage under both static and dynamic loading is done.

Structural and Multidisciplinary Optimization team:
The team focuses on development of mathematical models and numerical optimization methods for structural optimization of load carrying structures within wind energy. The research includes optimal design of composite structures such as wind turbine blades.

PUBLICATIONS



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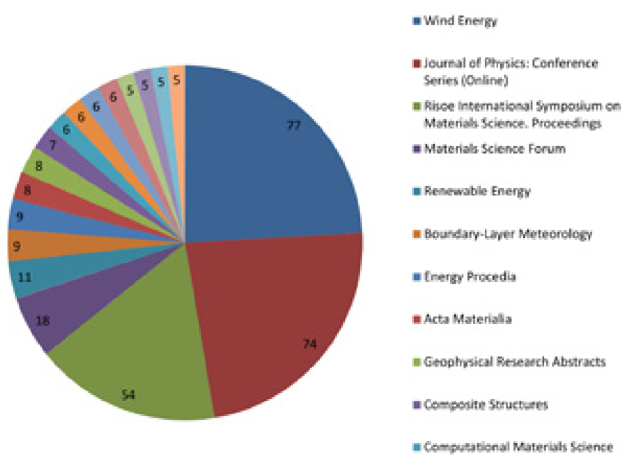

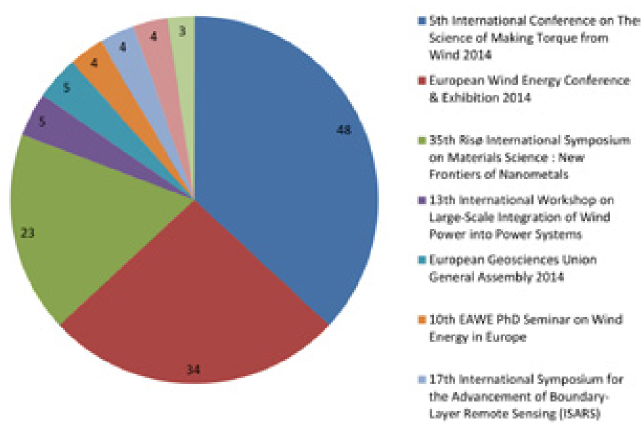

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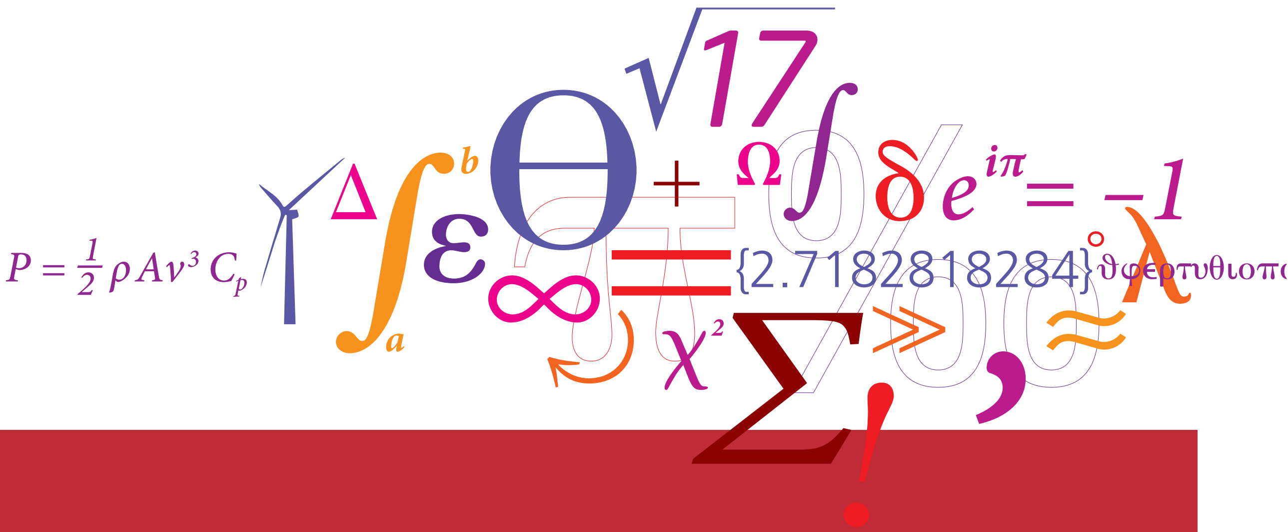

www.vindenergi.dtu.dk